Eagle Nest Monitoring Project: Year 1 2007–08

Establishing monitoring sites and investigating the relationship between nesting success of the Tasmanian wedge-tailed eagle and environmental variables

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Disclaimers

The information presented is a broad overview of information considered relevant (by the authors) to the project.

Analysis and discussion of information has been undertaken to different levels of detail.

Coverage of material may not be complete.

The opinions and interpretations of information in this document are made by the authors.

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Cover photograph of Tasmanian wedge-tailed eagle and chick by Bill Brown.

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Summary

1. This report covers the first year of a monitoring project that aims to evaluate the effectiveness of current management prescriptions in reducing adverse effects of activities covered by the forest practices system on the breeding success of the wedge-tailed eagle. The results of this long term project will assist in the ongoing development of management options.
2. The specific aims of the work carried out in the first year of the project (2007–08) were: to establish methods and nest sites for monitoring over the next five years; to explore the relationship between nest site and tree characteristics and the success of a nest site; and to evaluate the use of indirect signs in determining nest site 'activity status'.
3. The information in this report addresses the activities outlined in the project description and funding agreement (Appendix A). This project also contributes to recover action 6.1 detailed in the Recovery Plan for Threatened Eagles (Threatened Species Section, 2006).
4. The 2007–08 aerial and ground based surveys established a set of 84 nest sites around the state for future monitoring.
5. It was shown that a large proportion of nests are not used in any given year and that not all nests with an active bird presence produce chicks.
6. The results indicated that whether a nesting attempt was made was related to the presence and amount of both mature forest and roads. Both of these variables are likely to be related to the foraging behaviour of eagles.
7. The results indicate that wood production activities within a territory may be having an effect on nest success (production of a chick) but current data is insufficient to make strong conclusions.
8. At the tree level, this study found the best indication that a nest had been used was the nest condition, which is an assessment of nest structure. Loosely woven and collapsing nests indicate the nest was not used, while more intact nests increased the chance of nests being used to produce fledglings.
9. The presence of a chick at the nest is obviously the most important indicator of the success of a nest. However, when this is difficult to observe, the results from this study show that the presence of a flat top to the nest, green leaves, whitewash and prey remains are all useful indicators of nest success (chick presence).
10. Surveys conducted during this study suggest that there are many birds now breeding outside the August to January core breeding period originally noted by Mooney and Taylor in 1996. Some birds were found lining nests as early as April and some eagles were incubating as early as late July while others began in late September.
11. The results of the current study suggest that the level of disturbance within a broader spatial scale and impacts on productivity of eagles should be considered rather than just relying on protective measures close to a particular nest. The aim should be to minimise the rate and extent of disturbance within a territory to ensure the ongoing success of particular pairs.

Recommendations for future work include:

- Continue monitoring the 84 nest sites established in this study by increasing the number of activity checks by specialists to enable an assessment of nest failure (egg laid but no chick) and production of a fledgling. More frequent nest checks will also enable the timing of breeding to be better evaluated.
- Design a study to look specifically at type and nature of disturbance and impact on breeding pairs and their offspring resulting from different forestry activities.
- Design a study to look at foraging behaviour and range by a breeding pair of eagles. There is sufficient technology available to investigate 'animal movement' with the advent of satellite and GPS technologies. An analysis of foraging behaviour for breeding pairs in close proximity to intensive forestry would provide detailed information to better manage territories.
- Investigate the influence of forest patch size on nesting success. This was not possible in this study as the majority of nests were in patches >20ha.
- Further evaluate aspect and tree level factors to provide an updated model to predict wedge-tailed nesting habitat.
- Actions/recommendations to improve management of nest sites in areas subject to activities covered by the forest practices system.
- Improve the nest activity tracking system within the Forest Practices Authority.
- Training of planners in the identification of indirect signs.
- Develop a system to increase efficiencies during decision making processes while also providing a more up-to-date database and feedback system for FPOs.

Chapter 1
Introduction

1.1 Biology and conservation status

The Tasmanian wedge-tailed eagle *Aquila audax fleayi* is a forest-dependant breeder (Olsen 2005). It occurs throughout the state, including some large offshore islands. The genus *Aquila* is comprised of large eagles, with very strong legs and talons. The Tasmanian subspecies is larger than its mainland counter-part and is the fifth largest *Aquila* in the world (Brown and Amadon, 1989). It is the largest predatory bird and the only true eagle in Tasmania. It is listed as endangered under Schedule 1 of the *Commonwealth Environment and Biodiversity Conservation Act 1999* and Schedule 3.1 of the *Tasmanian Threatened Species Protection Act 1995* due to a low number of successful breeding pairs, loss and disturbance of breeding habitat and high mortality due to persecution and human-related accidents (Mooney, 1997).

The species suffered persecution from early colonial days (e.g. the Eagle and Tiger Extermination Society) and subsequent decline of Tasmanian wedge-tailed eagles has been attributed to farming practices, mainly during the 1970s. More recently, activities associated with intensive large-scale agriculture, rural residential developments and intensification of forestry activities have all potentially impacted on the Tasmanian subspecies**.** A population viability analysis for eagles in north-eastern Tasmania predicted a decline in the eagle population over the next 160 years if nest disturbance and unnatural mortality continue at the rates modelled (Fox *et al.*, 2004). The total population for Tasmania is currently estimated to be between 1000 and 1500 birds and the number of territories is estimated to be 426 (Threatened Species Section 2006).

Surprisingly, there have been few studies of incubation, nesting and post-fledging dependence in wedge-tailed eagles. This is unusual for such a large, iconic species, given the number of studies conducted on other *Aquila*'s of high conservation significance (Debus *et al.*, 2007). Most studies on wedge-tailed eagles have been conducted on mainland Australia. However the mainland subspecies, which occurs in greater numbers, is more tolerant of human disturbance (Olsen 1995). In common with the genus in general and wedge-tailed eagles elsewhere, wedge-tailed eagles nesting sites in undisturbed areas of Tasmania can be used for more than 50 years (Mooney pers. obs.). While there is an abundance of anecdotal material to indicate general population trends of Tasmanian wedge-tailed eagles, the paucity of scientific studies in Tasmania means there is a lack of detailed base-line data. This makes conservation planning difficult for this species (Threatened Species Section, 2006).

In common with other members of the genus, it is thought that wedge-tailed eagles will pair for life unless an individual dies, whereupon they may mate again (Olsen, 1995). Courtship generally occurs in June when eagles can be seen displaying and carrying sticks to refurbish nests. Large nest platforms, measuring an average 120 cm wide and 180 cm deep, are the focal points of eagle territories. One or two eggs are laid at the beginning of September, although the exact timing varies according to the season (Mooney and Taylor 1996b). While both birds are involved with incubation of the egg, the female incubates for the greater proportion of the time while the more agile male provides food for the pair. Incubation takes approximately 45 days and so chicks hatch around mid-late October. Siblicide may occur in the event where two chicks hatch (Olsen 2005). Chicks fledge at approximately 12 weeks, but may be seen with adults the following breeding season depending on food resources and the fledgling's ability to hunt for itself (Brown pers. obs.). Once fledged, it is estimated that approximately 60% of young die in their first year (Olsen 2005). Mortality thereafter greatly decreases. Sexual maturing is reached at four years for males and five for females (Mooney and Holdsworth 1991).

The diet of wedge-tailed eagles is varied. During the breeding season, mainly fresh prey is obtained, although individuals will scavenge more often during the winter when prey resources are scarce. Eagles are capable of killing animals up to three times their own body weight (15 kg), although they are only capable of carrying about half their weight (2.5 kg). Macropods, rabbits, birds and echidnas form the majority of the diet. Fish are known to be taken although rarely (Olsen 2005).

In general, habitat important for the breeding success of Tasmanian wedge-tailed eagles comprises native forests containing mature to old growth elements (Mooney and Holdsworth 1991). The species hunts over a wide range of habitats, but nests only in old growth trees on sheltered sites in native forests. At high densities, wedge-tailed eagles may nest as close as 700 m but more usually six km apart, with less productive areas 10–12 km (Olsen 1995). Nesting densities for *Aquila audax fleayi* are known to vary with habitat quality, with reported distances of 3–20 km between active nests in adjacent territories (Forest Practices Board 2000).

A description of significant habitat for this species was developed from published information and expert opinion for a recent document developed by the Forest Practices Authority to avoid or limit the clearance and conversion of significant habitat for threatened forest fauna (Forest Practices Authority 2008). Significant habitat includes both nesting and foraging habitat. Foraging habitat is described as a wide variety of forested (including areas subject to native forest silviculture) and non-forest habitats. Nesting habitat is described as tall eucalypt trees in large tracts (more than 10 ha) of eucalypt or mixed forest. Nest trees being amongst the largest in a locality in sheltered positions on leeward slopes, between the lower and mid slopes and with the top of the tree usually lower than the ground level of the top of the ridge. More than one nest may occur within a territory but only one is used for breeding in any one year. Breeding failure often promotes a change of nest in the next year (Forest Practices Board, 2000; Forest Practices Authority 2008).

Although mature forest habitat is known to be important for breeding, densities of the Tasmanian wedge-tailed eagle appear to be highest in areas with mosaics of forest, farmland, grassland, wetlands and rivers. The fragmentation of the Tasmanian forest landscape since European settlement into forest patches and cleared land has reportedly had some local benefit for this species (Mooney and Holdsworth 1991). Dense contiguous forest cover found in parts of Tasmania in the past may not have produced the densities of prey available in the more variegated landscape found in the same areas today. Extensive road networks also provide easy food for carrion feeding individuals (Olsen 1995). In Scotland, the breeding success of golden eagles *Aquila chrysaetos* is reduced when areas are planted with plantation species, due to the replacement of more open and productive hunting areas with dense forest canopies (Whitfield *et al.* 2001; Whitfield *et al.* 2007). Whitfield *et al.* (2007) further demonstrated that even increases of less than 10% canopy cover resulted in a large reduction in breeding success in golden eagles. Large scale plantations established in recent years across Tasmania have the potential to produce similar deleterious effects on the breeding success of the Tasmanian wedge-tailed eagle.

1.2 Management of wedge-tailed eagle nest sites

Management actions in Tasmania to aid eagle conservation have focussed on the protection of nesting habitat in areas subject to forestry activities (Mooney and Taylor 1996a). The majority of known nests occur on state forest and private property (47.8% and 42.7% respectively: Threatened Species Section 2006) and are thus in areas potentially available for timber harvesting. Early research on the effects of forestry disturbance on eagle breeding success made recommendations that resulted in the adoption of the current 10 ha minimum nest reserves although the recommended additional 10 ha buffer was never instigated (Mooney and Holdsworth 1991). Subsequent monitoring of the effectiveness of the nest reserve in the late 1980s and early 1990s found the minimum reserve was effective in providing buffers from human disturbance as long as strict disturbance controls were also investigated (Mooney and Taylor 1996b). This work led to the requirement for pre-logging nest surveys which has assisted in a decrease in the number of nests disturbed during forestry operations (Mooney 2000).

Development of a predictive model of nesting habitat of the wedge-tailed eagle has assisted in targeting areas to search (Brown and Mooney 1997; Threatened Species Section 2006). Current additional measures to minimise disturbance to a particular nest include a 500 m (out of sight), and 1 km (line of sight) 'no-activity' exclusion zone if nests are found to be active following a pre-logging assessment conducted during the breeding season (August–January) (Threatened Species Section, 2006). Forest planners provide annual reports to the Threatened Species Section (TSS) on the number of nests in proximity to planned forest operations. During the second week of September and November, 'nest activity checks' are conducted by trained officers. These management actions are currently implemented via the Tasmanian forest practices system (Forest Practices Board 2000; Munks and Taylor 2000; Forest Practices Board 2002).

In the last seven years, these prescriptions have been developed further and now include a range of additional provisions to cover the variety of different activities covered by the forest practices system. These include the development of a 'visibility model' to assist with implementation of the 500 m and 1 km 'line of sight' exclusion zones (Appendix B). Preliminary monitoring by the Forest Practices Authority indicates that the current provisions are applied in Forest Practices Plans (Munks *et al.* unpublished data) but further assessment is required to assess the standard to which they are implemented in operations. Information is also required on whether or not they are meeting conservation objectives. This is important as the move by the Tasmanian forest industry to more intensive plantation forestry and the subsequent large landscape changes that have occurred in recent years could result in significant influences on current eagle reproductive rates, if current management practices are inadequate.

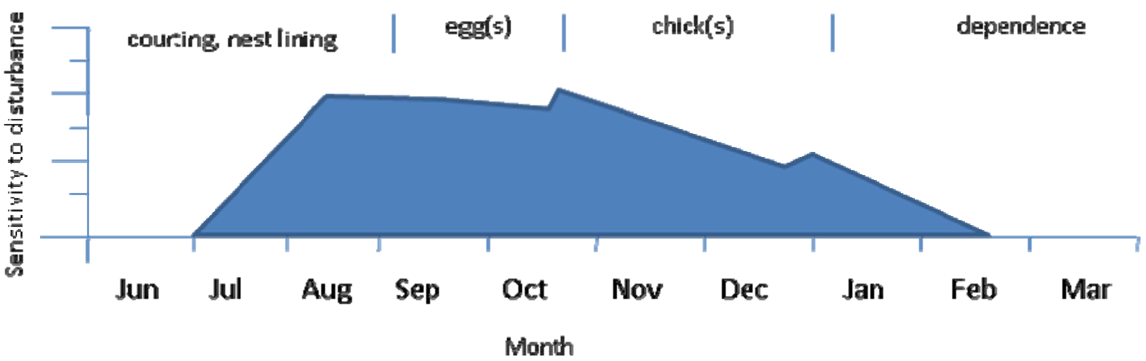

Figure 1 Sensitivity of breeding wedge-tailed eagles to nest disturbance. The shading represents the degree of sensitivity (Mooney and Holdsworth 1991).

1.3 Aim of study and structure of the report

This report covers the first year of a monitoring project that aims to evaluate the effectiveness of current management prescriptions in reducing adverse effects of activities covered by the forest practices system on wedge-tailed eagle breeding success. The results of this long term project will assist in the ongoing development of management options.

The specific aims of the work carried out in the first year (2007–08) of the project, covered in this report, were:

1. to establish methods and sites for long-term monitoring
2. to explore the relationship between nest site and territory characteristics (including disturbance categories) and the success of a nest site
3. to explore the relationship between tree level characteristics and the success of a nest site
4. to evaluate the use of indirect signs in determining nest site success both for pre-operation 'activity checks' undertaken during the breeding season and monitoring of nest success post breeding season.

Chapter 2 of this report covers the selection of nest sites and the results of the (2007–08) monitoring season. This chapter also reports on preliminary analysis carried out to address the second and third aim. An attempt was made to use existing data for known nest sites collected by forest planners over the past four years. This, however, was unsuccessful due to inconsistency in the data available caused by large variation in the methods used and changes in observers.

Chapter 3 covers the fourth aim and reports on the value of indirect signs, identifying those of most use for forest planners carrying out 'activity checks'.

Chapter 4 provides a final discussion of the first year of work and recommendations for future work. It also discusses implications for management.

The information in this report addresses the activities outlined in the project description and funding agreement (Appendix A). This project also contributes to recover action 6.1 detailed in the Recovery Plan for Threatened Eagles (Threatened Species Section, 2006).

Chapter 2
Relationship between nest site success and habitat variables

2.1 Introduction

The breeding biology of the mainland wedge-tailed eagle has been variably reported (Olsen 1995, 2005; Debus *et al.* 2007). While the Tasmanian subspecies has many similarities to its mainland counterpart, the more secretive nesting behaviour of *fleayi* means it remains relatively poorly known. Work by Mooney and Holdsworth (1991) and Mooney and Taylor (1996) and Mooney (1997) detailed many of the management issues unique to the Tasmanian wedge-tailed eagle including the sensitivity of breeding pairs to disturbances at nest sites. Failure of breeding attempts by Tasmanian wedge-tailed eagles at a particular nest site can be a result of a range of natural causes (e.g. fire, extreme storm event). However, disturbance by a range of anthropogenic activities (e.g. forestry, agricultural activities and recreation) is also considered to be a major cause of nest failure. Mooney and Taylor (1996) report the Tasmanian subspecies as particularly intolerant to disturbance by nearby intensive forestry activities or less intensive but focused (at the nest level) activities. The degree to which these threats impact on a breeding pair may be estimated by monitoring the use of a particular nest site during and over successive breeding seasons. Identifying any changes to the use of a particular nest site can assist in understanding the threatening factors at a site and facilitate development of management actions to ameliorate impact.

Intensification of forestry operations in areas outside of the reserve system over the past 12 years (Lindenmayer and Franklin 2002) have produced a situation in which many wedge-tailed eagle territories have undergone extensive changes including conversion of extensive areas of native forest and previously cleared land to plantations and intensification, in time and space, of native forest operations. The increase in rural residential development and changes to primary production in agricultural areas has also altered landscapes on a large-scale (Thurstans 2009). There is some anecdotal evidence that suggests a move away from traditionally used nest sites by eagles in areas that are intensively managed for wood production (Mooney 2000).

Of the 57 nests previously surveyed by Mooney (1997), 44 were found derelict, fallen or not viable in 2007–08, only 24 were viable, with the minimum estimated age being seventeen years (Mooney unpublished data). Eagles have recently and increasingly been observed nesting in environments previously considered less than suitable (DPIW 2008). A large proportion of eagle nests known in Tasmania are in areas subject to production forestry activities. During the (2007–08) breeding season, 250 nests (of which those, productive nests would represent approximately 1/3 of the state's eagle breeding population) were surveyed by forestry industry planners as part of the coupe planning process.

The results of these surveys indicate a significant increase in the number of new nests i.e. 50% of nests recorded were newly built/previously unknown. This large increase in new nests is not thought to be a result of increased eagle numbers, but rather an increase in the number of nests within a territory (Brown unpublished data). Although this result may, in part, be explained by more intensive and skilled search methods, it may also be due to the increasing degree (rate and extent) of disturbance within a territory (Mooney and Taylor 1996a). This observation needs to be examined further as ongoing disruption of a particular territory could theoretically result in a cascading negative effect on neighbouring territories and other pairs of eagles attempting to breed across the landscape. Further work at the landscape level is needed on the factors that influence nesting success within a particular territory.

The aim of the study was to establish a set of sites for long-term monitoring of breeding success in areas subject to current wedge-tailed eagle nest management prescriptions and in areas with minimal disturbance. Preliminary data collected in the 2007–08 season has been used to explore the relationship between site and tree level characteristics (including disturbance categories) and the success or otherwise (activity status) of a nest site.

2.2 Methods

2.2.1 Nest site selection

Nest sites, located on State forest and private land, were selected from the Raptor Nest Database (DPIW 2007). GIS analysis was used to randomly select 80 nests that were subject to forestry activities and current wedge-tailed eagle nest management prescriptions. These nest sites will be referred to as 'managed' nest sites. A further 80 sites were selected from areas not subject to forest practices within 1 km of the nest, according to GIS information. These sites will be referred to as 'semi-natural' sites. Of the semi-natural nest sites, 30 were found during aerial surveys to be disturbed and so were removed from the dataset. A further 24 nests were removed following the survey as they no longer existed or were now part of different land tenure. The history available for the remaining 106 nest sites is provided in Appendix C. A decision was made to remove 22 of these sites from the final sample. These sites had existing data collected by forest planners over the past four years but there were large inconsistencies in the data caused by variation in the methods used and changes in observers.

The remaining 84 nests included 49 managed and 35 semi-natural nest sites scattered around the state (Figure 2.1).

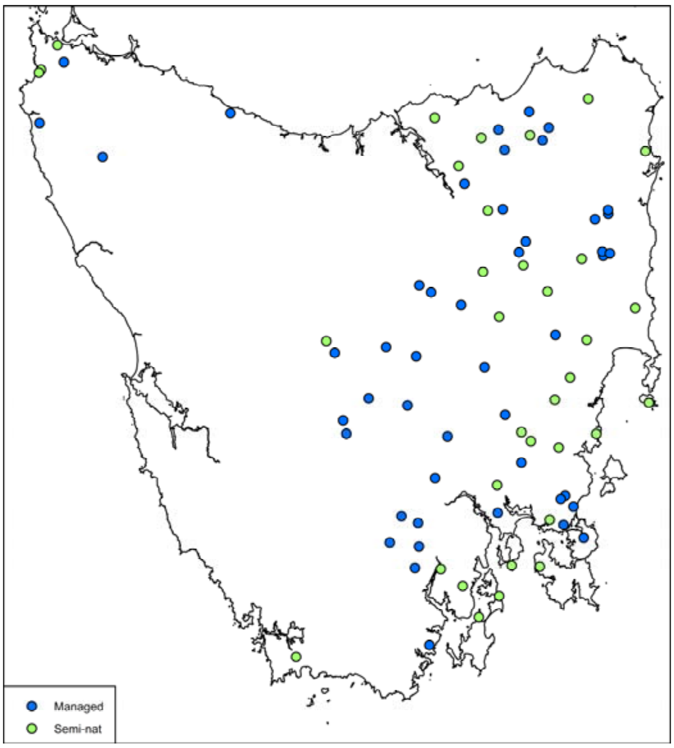

Figure 2.1 Location of managed and semi-natural nest sites monitored during 2007–08

2.2.2 Nest Activity Assessment

Of the 84 nests (49 managed and 35 semi-natural sites), 76 were visited during November 2007 by fixed wing aircraft. The remaining eight nests could not be located during aerial surveys and so were surveyed from the ground by eagle specialists or forest planners during late November 2007 (Figure 2.1). Each nest surveyed was allocated an 'activity status' category. There are a number of nest site characteristics that have been used by eagle specialists over the years to define nest status (Appendix D). The characteristics used in this study to define the activity status of a particular nest are detailed in Table 2.1.

Table 2.1 Nest activity status categories

Activity status No.	Activity status	Observation
0	Not used [1]	No signs of use, nest slumped and may be partially or fully bleached.
1	Maintained [1]	Sign of use[2] (e.g., significant signs of a compact nest platform, significant amounts of white-wash, green leaves, recently added brown sticks) but no egg or chick observed.
2	Successful	Egg, chick and fledging. Nests were considered "successful" if they contained a chick 6 weeks or older and where significant amounts of down was present around the immediate nest [1]

[1] Nests classified as 'not used' or 'maintained' are collectively referred to as being 'unsuccessful'.

[2] Nest sites occupation could be determined by investigating whether fresh white-wash, recently added green leaves and brown sticks had been added to the nest rim. During the early phases of breeding, green leaves continue to be added to a nest throughout the breeding attempt. White-wash (faecal matter) accumulates over time immediately below the nest or underneath limbs used as butcher sites or roosting platforms. Prey remains can also accumulate under a nest and so are a sign of nest use that becomes more obvious as the season progresses. Note: the quantity of whitewash is important to consider since vacant nests may contain white-wash, as adults frequent secondary or tertiary nests in their territory, although they may not be used for breeding.

2.2.3 Habitat variables

2.2.3.1 Site level

Site level habitat data was gathered for the 84 nests surveyed using GIS techniques in the program ArcGis 9.2 (Environmental Research Institute, ESRI 2007). Site level is defined as the areas encompassed within a 6 km radius from each nest site. GIS data was supplied under licence by Forestry Tasmania, Gunns LTD, Private Forests, Norske Skog and obtained from DPIW's Natural values Atlas (NVA) and FPA's databases. The variables examined (Table 2.2) were selected because of their likely influence on the breeding activity of a particular nest site and because there was available GIS information. The availability of different vegetation types was quantified within concentric radii (500 m, 1000 m and 6000 m from each nest tree). Different radii were examined to investigate the scale at which site modifications may impact eagle breeding activity. The first two radii relate to current management practices. The 6000 m radius was selected for examination because this is the estimated homerange of a similar sized predatory bird, the white-bellied sea eagle (Wiersma 2009). No previous work has detailed homeranges for wedge-tailed eagles in Tasmanian.

The size (ha) of the patch of intact forest in which each of the 84 nests surveyed for activity was situated was determined by finding the area of connected TASVEG polygons (i.e. a polygon that shares a common edge with homogeneous veg group class,(Department of Primary Industries and Water 1996). This was not distance limited i.e. it includes all connected area not just that limited to a 6 km range.

Table 2.2 Description and source of site variable data and an indication of how the data was treated during the model-building process

Site Level Variables	Description
Plantation †§Ω	Area (m^2) within each radii that is classified as 'plantation' in the database '*the List* 2008' forest group layer.
Dry Eucalypt Forest †§Ω	Area (m^2) within each radii that is classified as 'dry-eucalypt forest' using the TASVEG 1.3 (2006) layer
Wet Eucalypt Forest †§Ω	Area (m^2) within each radii that is classified as 'wet eucalypt forest' using the TASVEG 1.3 (2006) layer
Non-Eucalypt Forest †§Ω	Area (m^2) within each radii that is classified as 'non-eucalypt forest' using the TASVEG 1.3 (2006) layer
Rainforest †§Ω	Area (m^2) within each radii that is classified as 'rainforest' using the TASVEG 1.3 (2006) layer
Scrubland †§Ω	Area (m^2) within each radii that is classified as 'scrubland' using the TASVEG 1.3 (2006) layer
Sedgeland †§Ω	Area (m^2) within each radii that is classified as 'sedgeland' using the TASVEG 1.3 (2006) layer
Highland Vegetation †§Ω	Area (m^2) within each radii that is classified as 'highland vegetation' using the TASVEG 1.3 (2006) layer
Aggregated Vegetation†§Ω	Area (m^2) within each radii that is classified as 'aggregated vegetation' using the TASVEG 1.3 (2006) layer
Native Grassland †§Ω	Area (m^2) within each radii that is classified as 'native grassland' using the TASVEG 1.3 (2006) layer
Other Natural Environments †§Ω	Area (m^2) within each radii that is classified as 'other natural environments' in the TASVEG 1.3 (2006) layer. This classification largely considers water bodies such as lakes.
Mature Eucalypt Forest †§Ω	Area (m^2) within each radii defined as having a predominantly 'mature' or 'senescent' (over-mature) canopy, extracted from Forestry Tasmania's, Private Forests, MDC and PI-type data extract, 2007. E.g. PI-types E+3b.ER.S. E2d.ER2d.T. M+. Tw.
Regrowth Forest †§Ω	Area (m^2) within each radii defined as being predominantly regrowth forest, extracted from Forestry Tasmania's, Private Forests, MDC and PI-type data extract, 2007. Regrowth trees are identified according to the shape of the crown, but are trees older than 20 years. E.g. PI-types ER4c/1.T.S. ER2c.E+3d.
Young Regenerated Forest †§Ω	Area (m^2) within each radii defined as being predominantly native regeneration less than 20 years old (regenerated forest), extracted from Forestry Tasmania's, Private Forests, MDC and PI-type data extract, 2007. E.g. PI-types E(98)A/2. E(84,78)1b/+3. E(85)W.fd ER2d/1. E(87)P.Tw.E-3f.
Potential Nesting Habitat †§Ω	Area (m^2) within each radii of potential nesting habitat as modelled by Threatened Species Section, DPIW (Appendix E, adapted from Brown and Mooney 1997). Formulated using Forestry Tasmania, Private Forests MDC and PITYPE and Tasveg data sets.

Site Level Variables	Description
Other known Nests [†§Ω]	Number of other known eagle nests within each radii. Derived from existing eagle nest database managed by DPIW.
Length of Road [†§Ω]	Total length of road (m) within each radii, estimated using '*the List* 2008' Transport layer as maintained by the Department of Infrastructure Energy and Resources Tasmania.
Total Area Replanted [†§Ω*]	Total Area (m^2) within each radii that was replanted between 01/07/2005 and 30/06/2008 according to Forestry Tasmania's Operations Database (2008).
Mammal Control[†§Ω*]	Area (m^2) subject to mammal control activities between 01/07/2005 - 30/06/2008, as identified from Forestry Tasmania's Operations Database (2008).
Harvested [†§Ω*]	Area (m^2) within each radii that was harvested between 01/07/2005 and 30/06/2008, extracted from Forestry Tasmania's Operations Database (2008).
Altitude[§]	Approximate altitude at nest site (m^{ASL}) as estimated using Spline Interpolation from Tasmanian 10m contour data DPIW, Tasmap data.
Slope [§]	Approximate slope at nest site (^{o}) extracted from Tasmanian 10m contour data DPIW, Tasmap data.
Aspect [§]	The aspect of the site on which the nest tree is located as extracted from DPIW, Tasmap data. Aspects were classified as (1) flat; (2) 0^o-60^o; (3) 61^o-120^o; (4) 121^o-180^o; (5) 181^o-359^o.
Cleared land [§]	Distance (m) to closest cleared land. Derviced fromTASVEG field Agricultural, urban and exotic vegetation 1.3 (2006) data.

† Data was logged. § Data was standardised. Ω Variable was examined in a 500m, 100m and 600m radius from the nest.* Does not include such activities on Private Land as data was not available.

2.2.3.2 Tree level

Ground-based surveys were done after the breeding season (May 2008) on 21 nests. The nests examined were selected opportunistically from nests that could be checked from the ground by telescope (Figure 2.2). During these surveys, detailed information was collected on the nests, nest trees and immediate area surrounding the nest (Table 2.3). The variables examined were selected because of their likely influence on breeding success as identified in the literature. Additional information on some of these sites was obtained through the analysis of Tasmap topographic map features (DPIW) using co-ordinate datum to extract specific fields using ArcGis 9.2 (Table 2.3).

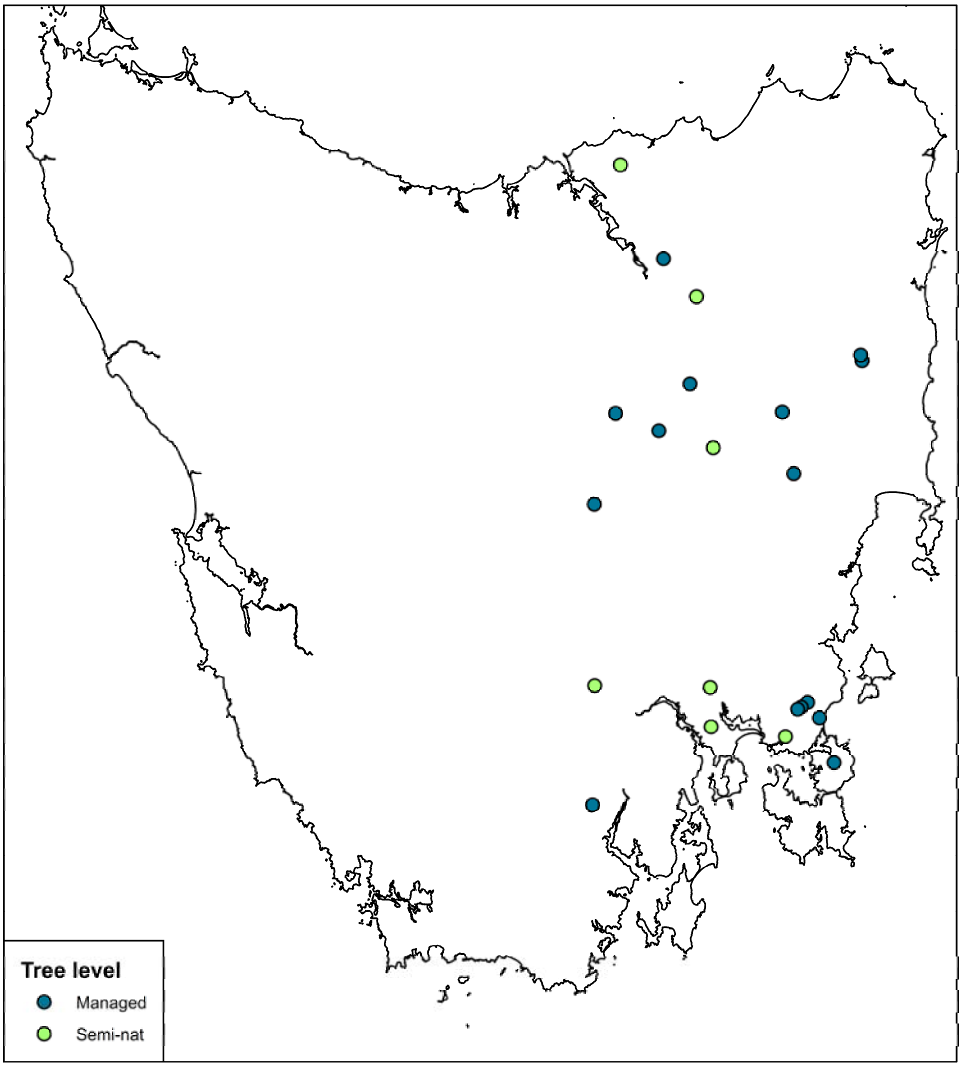

Figure 2.2 Location and category of nest sites for which tree-level data was gathered in 2007–08

Table 2.3 Description and source of tree variable data and an indication of how the data was treated during the model-building process

Tree level variables	Description
Brown leaves	A subjective assessment from the ground on whether brown leaves (recently added green leaves which have turned brown) are (1) absent or (2) present in the nest.
White wash	A visual assessment from the ground on whether white wash (faecal matter) was (1) absent or in very low levels in the nest or (2) present at the nest in reasonable amounts.
Pellets	A visual assessment from the ground of whether regurgitated pellets were (1) absent or (2) present in the nest.or on the ground
Prey remains	A visual assessment from the ground of whether prey remains were (1) absent or (2) present in the nest.
Bleach	A visual assessment from the ground on whether the nest was (1) unbleached by the sun or (2) had been at least partially bleached.
Base decay	A visual assessment of whether the base of the nest was partially decayed or not.
Green leaching	A visual assessment of whether green liquid was leaching from the base of the nest or not
Nest condition	A subjective assessment of nest condition based on morphology. Low: Nest loosely woven and collapsing; Medium: nest showing some signs of collapse but is largely intact and compact; High: Structurally intact and compact.
Nest depth	Estimated depth (cm) of the nest
Nest width	The width of the nest (cm) at the widest point estimated from the ground. This is calibrated using estimates of trunk diameter.
Nest support structure	An assessment of the location of the nesting platform as being in (1) primary branch, (2) secondary branch, (3) trunk fork.
Nest height	Height (m) of the nest in the tree measured using a laser range finder
Nest tree height	The height (m) of the nest tree measured using a laser range finder
Branch height	Distance (m) from the ground to the lowest branch, measured using a laser range finder. [§]
Nest tree dbh	The diameter at breast height of the nest tree (cm), measured using a diameter tape. [§]

Tree level variables	Description
Canopy above nest	An estimated percentage of canopy cover above the nest classified as ≤25% or >25%.
Canopy below nest	An estimated percentage of canopy cover below the nest classified as ≤10% or >10%.
Senesced percent	A visual estimate of the percentage of the nest tree crown that is senescent[†§]
Fire tree base	An assessment whether there was (1) no evidence of fire damage or superficial damage to the bark only or (2) evidence that fire had damaged the wood of the tree.
Slope	Slope (°) of the site measured using a clinometer. [§]
sin(Aspect)	A compass was used to determine site aspect, the direction directly down-slope (°). This variable is the sin of site aspect. [§]
cos(aspect)	The cos of site aspect. [§]
Category	A subjective assessment of land management practices: Semi-natural: surrounding area not available for timber harvesting and comprised of intact forest with a minimal history of human activity; Managed: surrounding land managed by the forest industry but may or may not have a history of harvesting
Total Basal Area P1	An assessment of site basal area estimated using a prism (size 4). [†§]
Total Basal Area P2	An assessment of site basal area estimated using a prism (size 4). [†§]
Total Basal Area P3	An assessment of site basal area estimated using a prism (size 4). [†§]
Restricted access	An assessment of the presence of gates or locked entry points on the roads closest to the nest tree. This was determined from on-site visits.
Floristic forest type	A classification of the broad forest type within which the nest tree was located as (1) dry or (2) wet according to RFA forest type classifications (Forest Practices Authority 2005)
Recruitment	A subjective assessment from the ground on whether other mature trees that could potentially hold nesting platforms were available at suitable locations (aspect and slope) within the patch of forest around the nest or within an approximate 500 m radius. Potential trees were assessed as being (1) present, (2) absent or (3) uncertain.

Tree level variables	Description
Distance from road	The distance (m) from the nest tree to the nearest road (sealed or unsealed) using either a laser range finder or GPS coordinates[†§]
Distance nest cleared	The distance (m) from the nest tree to the closest cleared area. The location of cleared areas was determined from ground surveys. [†§]
Closest human activity	The distance (m) from the nest tree to the nearest human activity (e.g. harvesting, roads, woodcutting etc.). Human activity was determined from ground surveys. [†§]

† Data was logged after the addition of one unit to each data point to cater for data with a value of zero. § Data was standardised.

2.2.4 Data analysis

Chi-square analysis was used to determine whether past reports of reproductive rates and forest patch size were significantly different. Chi-Square was also used to examine the significance in success, unsuccessful nests in managed and semi-natural environments as a preliminary investigation to see if general trends could be observed without using more complicated Bayesian Logistic Regression Models.

2.2.4.1 Site level

To examine the site variables relating to an increase in nesting success, as determined by increasing activity status category (Table 2.1), two Bayesian logistic regression models were constructed. The first 'use: non-use' model compared sites with an active presence at the nest (categories 1 and 2) against those with no presence (category 0). The second 'success: failure' model compared sites where nesting attempts were successful (category 2) with all other nests where no breeding occurred (categories 0 and 1). These models are not independent, but address different levels of breeding activity from the same data set.

A large number of site variables were examined in the model construction (Table 2.2). Model selection was done using a forward stepwise approach. For the model building process, all continuous variables were standardised to reduce autocorrelation between successive samples (mean subtracted from the value, then all divided by the standard deviation: McCarthy 2007). Once an optimal model was identified, the model was re-analysed using data that was not standardised, to better facilitate model interpretation. This resulted in a slight change in the importance of some of the predictor variables and, hence, a slight modification of the final model. It is noted in the results section where this occurred.

The majority of variables containing data for different radii were zero-inflated and so were entered using a two-part method. Each variable was entered categorically as present/absent, in addition to which a linear relationship was applied to all positive values of the logged variable. Variables were logged to remove the effect of outliers which were present for a large number of variables. A small number of the variables with data at different radii were entered only as categorical or continuous variables. This was only done if the two-part method didn't work due to the distribution of the data (e.g. very few positive values or a lack of variability in the positive values). A small number of variables could not be assessed at each step because of a lack of variability in the data. No interactions or alternate relationships were considered. Once the final model was established, the distribution of the data in the remaining variables was examined and, if appropriate and variable significance was retained, variables were changed to a continuous form only. It is indicated in the results where this has been done. The results of the final model were used to construct a predictive model. The predicted results for the data were compared against observed results to examine model fit.

For the current models, the analysis was done in WinBUGS 1.4 (Spiegelhalter *et al.* 2003) using uninformative priors. The initial 1000 samples were discarded as a 'burn in' (to allow the model to stabilise) and the following 10 000 samples were used to calculate the Deviance Information Criterion (DIC). DIC values can be interpreted in a similar way to AIC values (Burnham and Anderson 2002; Spiegelhalter *et al.* 2002) and were used for model selection. A difference in DIC value of less than two indicates a lack of difference in the models, while a difference of three of more indicates that the model with the smaller DIC value is superior (McCarthy 2007). Due to the large number of predictor variables that were examined, a difference in DIC of at least five was required for a variable to be retained in the model. However, DIC values of three or greater were examined in the model selection process where fewer than five predictor variables were already included in the model. This was to 'over-fit' the model in case the addition of further variables increased the contribution made by other variables. However, all over-fitted models were then pared back to ensure that each variable in the final model resulted in a decrease in DIC value of at least five units. After selection of the final model, 100 000 samples were taken to establish model parameters. The mean, standard deviation and the 2.5th and 97.5th percentiles of the model coefficients were calculated. The percentiles represent a 95% Bayesian credible interval. In addition, the fit of the model, and change in model fit as a result of including each variable, was assessed by the following formula which estimates the proportion of deviance explained by the fitted model:

$$GOF = (Dhat_1 - Dhat_0) / Dhat_0$$

where:

GOF = Goodness of fit measure

$Dhat_1$ is the Dhat value produced by WinBUGS for the fitted model (the Dhat value represents the deviance at the mean of the posterior distribution: McCarthy 2007).
$Dhat_0$ is the Dhat value where all parameters are removed except an uninformative constant .

2.2.4.2 Tree level

To examine the tree level variables relating to an increase in nesting success, as determined by increasing activity status category, model structure and selection procedure were the same as for the site level analysis. The predictor variables examined are outlined in Table 2.3. The exception is that no continuous variables were entered using the two-part method as zero inflation was not an issue with the tree level data set. Not all categorical variables could be assessed in each step because of a lack of variability in the data.

2.3 Results

2.3.1 Nest activity status

A relatively small proportion (26%) of the 84 nests examined in the first year of survey were successful (Table 2.4). Successful nests were distributed evenly across the state (Figure 2.3). Over half of the nests examined (56%) showed no recent signs of use. The remaining 18% of sites showed signs of activity but no successful breeding ('maintained' category) (Table 2.4).

A slightly higher proportion of nests were successful in areas least disturbed by forestry practices (semi-natural sites: 34%) than forestry areas subject to wedge-tailed eagle nest management prescriptions (20%) (Table 2.4, Figure 2.4). However there was no statistically significant association between the activity status of nests and land use category (managed and semi-natural) ($X^2_1 = 1.379$, $p>0.05$).

Table 2.4 A summary of the activity status for the nests examined in relation to land management in 2007–08

Nest Category	Not Used (0)	Maintained (1)	Successful(2)	Total No.
Managed	30	9	10	49
Semi-Natural	17	6	12	35
Total	47	15	22	84

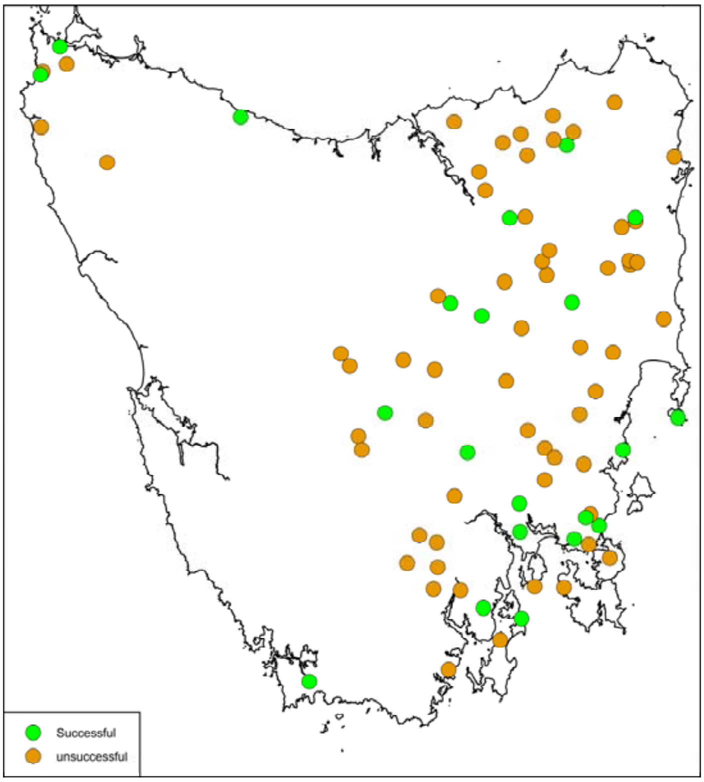

Figure 2.3 Location of successful nests and unsuccessful nests (not used or maintained) from 2007–08 surveys

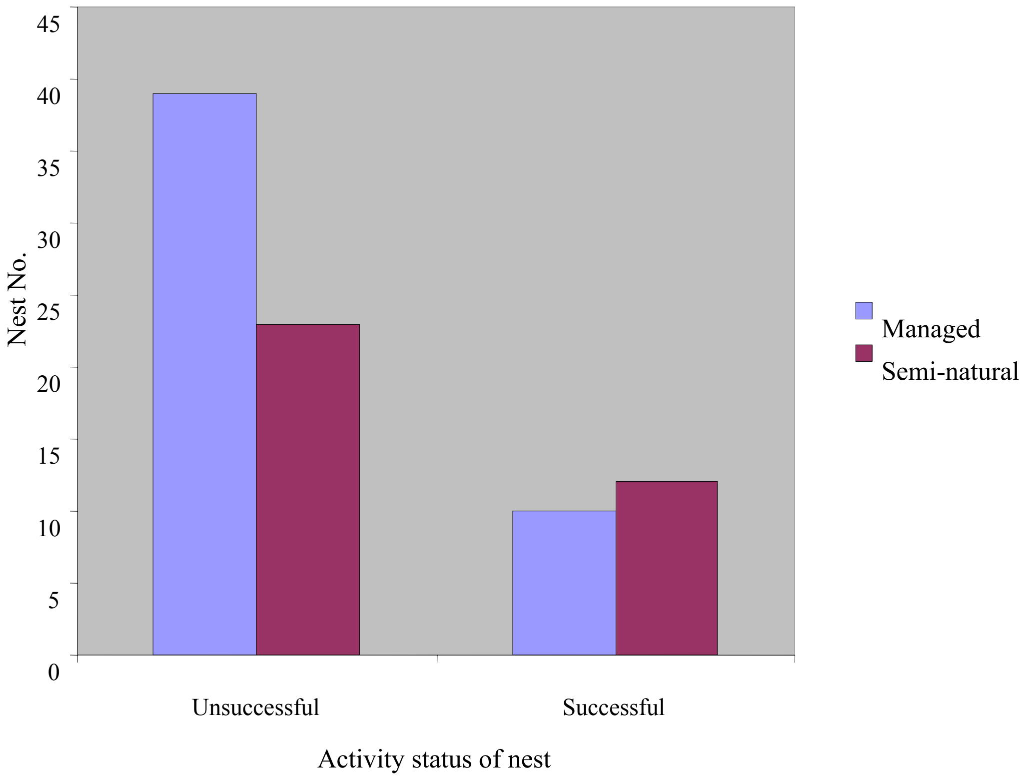

Figure 2.4 Number of nests in each land use category (managed and semi-natural) that were successful and those that were unsuccessful (categories 0 or 1 Table 2.1)

The majority of nests surveyed were in patches of connected native forest that were greater than 20 ha in area. Two of the eight nests located in patches smaller than 20 ha were successful (Table 2.5).

Table 2.5 Nest success according to patch size

Patch size (ha)	Successful	Unsuccessful	Total
<10ha	2	2	4
10-20	0	4	4
>20	18	58	76
Total	20	64	84

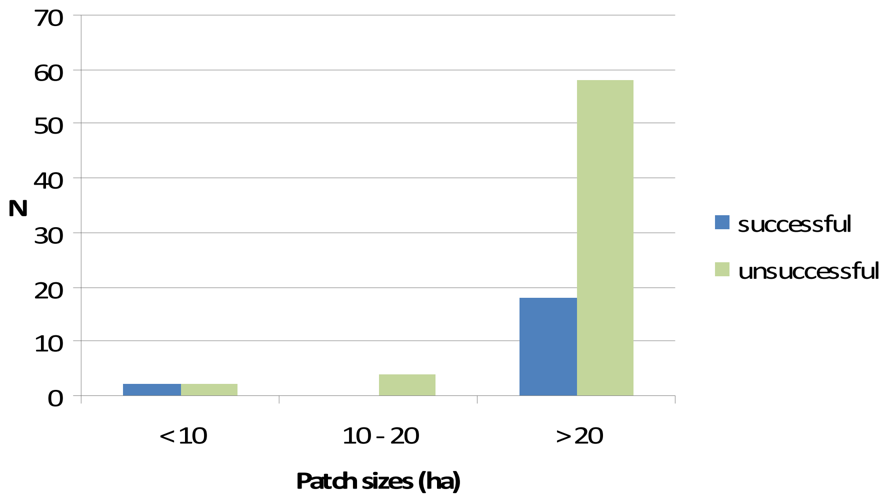

Figure 2.5 The number of nests in different sized forest patches

2.3.2 Timing of breeding

During the November/December 2007–08 activity checks, the majority of nests contained four to five week old chicks but one week old chicks were observed in a small number of nests. Exploratory observations made during a few early checks found birds lining nests in April and incubating in early July, while others were not incubating until late September. It was estimated that 12% of chicks did not leave the nest until late February and 16% of breeding pairs started nesting before August.

2.3.3 Relationships between site variables and nest activity status

2.3.3.1 Use:Non-use model

The amount of mature eucalypt forest in a 6 km radius and the length of road in a 500 m radius around the nest were related to whether an attempt at nesting was made, explaining 18.9% of the variability in the data as determined by the GOF measure (Table 2.6). There was an initial drop in likelihood of a nesting attempt with the presence of roads, but where roads were present, nesting attempts were more likely to occur as the Amount of Road in the area increased (Table 2.7, Figure 2.6). Sites with no mature forest were less likely to be used for a breeding attempt, but where present within 6 km, the likelihood a nesting attempt was made decreased with amount of mature forest.

Table 2.6 The change in DIC and GOF values when the stated variables are removed from the final site level success: failure model

Variable	DIC	GOF
Base		
Log (Mature Forest within 6 km)	12.4	11.4
Log (Road Length within 500m)	8.9	14.4

Table 2.7 The mean, standard deviation, 2.5th and 97.5th percentile values for the posterior distribution of the parameters in the final site level success: failure model

Variable		Odds Ratio	Mean	SD	2.5th	97.5th
Base		0.409	-0.893	0.934	-2.850	0.824
Log (Mature Forest within 6 km)	Binomial	8.1E+05	13.610	4.189	6.173	22.370
	Continuous	0.464	-0.767	0.246	-1.284	-0.335
Log (Road Length within 500 m)	Binomial	2.3E-06	-13.000	4.042	-21.53	-5.658
	Continuous	4.60	1.526	0.479	0.654	2.542

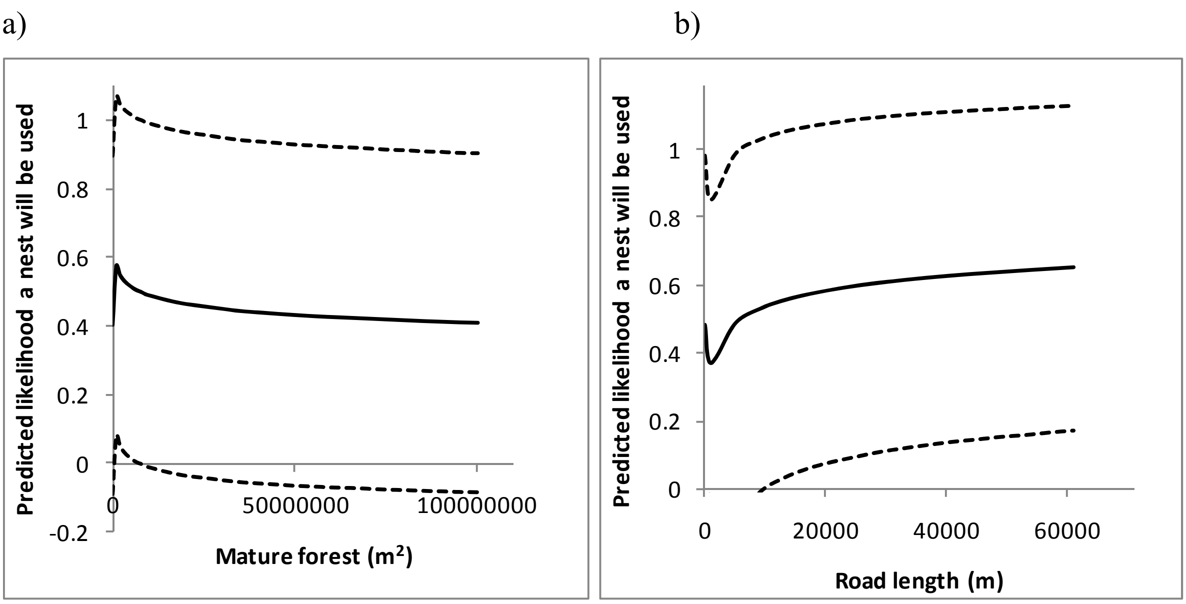

Figure 2.6 The predicted likelihood a nest will be used in relation to (a) amount of mature forest in a 6 km radius and (b) length of road in a 500 m radius, when other variables are held at their average value (Mature forest: 21672251.8 m2; Road length: 3427.9 m). The solid line represents the mean prediction and the dashed lines are one standard deviation around the prediction.

2.3.3.2 Success:Failure

The successful production of a chick in the nest was related to the area harvested in a six kilometre radius around the nest (Table 2.8). This model explained 12.7% of the variability in the data, as determined by the GOF measure. The harvested area was entered as a two-part variable during model selection. However, when examined as a continuous variable, the DIC rating of the model improved by two points and so it is presented as a continuous variable in the final model. An increase in area harvested within 6 km was related to a decrease in breeding success (Table 2.9, Figure 2.7).

Table 2.8 The change in DIC value when the stated variables are removed from the final the level success: failure model

Variable	DIC
Base	
Log(Area harvested 6km)	9.82

Table 2.9 The odds ratio is the probability of the mean, standard deviation, 2.5th and 97.5th percentile values for the posterior distribution of the parameters in the final site level success: failure model

Variable	Odds Ratio	Mean	SD	2.5th	97.5th
Base	0.800	-0.2235	0.3439	-0.909	0.4459
Log(Area harvested 6km)	0.873	-0.136	0.0424	-0.2239	-0.05741

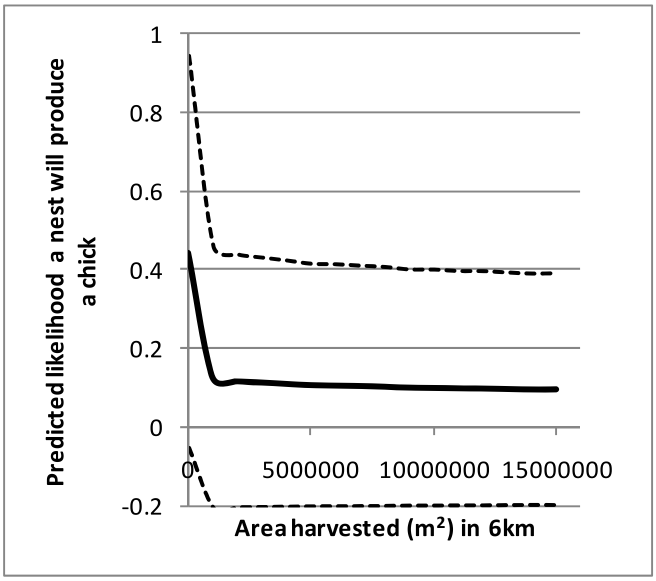

Figure 2.7 The predicted likelihood a nest will be successful (produce a chick) in relation to the area harvested within a 6 km radius. The solid line represents the mean prediction and the dashed lines are one standard deviation around the prediction.

2.3.4 Relationship between tree level variables and nest activity status

2.3.4.1Use:Non-use model

Nest Condition, a subjective measure of nest quality, was the variable most strongly related to whether an attempt at nesting was made. Combining categories 'medium' and 'high' did not result in a loss of explanatory power (Table 2.10). The final model (two categories) explained 26.1% of the variability in the data, as determined by the GOF measure. The results indicate that sites were more likely to be used with increasing nest condition (Table 2.11, Figure 2.8). Alternative models that either had slightly lower explanatory power or were unstable due to a lack of variability in the data included brown leaves, white wash, canopy below nest and nest support structure.

Table 2.10 The change in DIC value when the stated variables are removed from the final tree level use: non-use model

Variable	DIC
Base	
Nest Condition* (3 categories)	3.07
Nest Condition (2 categories)	5.23

(Nest Condition: 1 = low, 2 = medium, 3 = high)

Table 2.11 The mean, standard deviation, 2.5th and 97.5th percentile values for the posterior distribution of the parameters in the final tree level use: non-use model

Variable	Odds ratio	Mean	SD	2.5th	97.5th
Base	0.127	-2.067	1.347	-5.222	0.087
Nest Condition	36.089	3.586	1.513	1.024	6.970

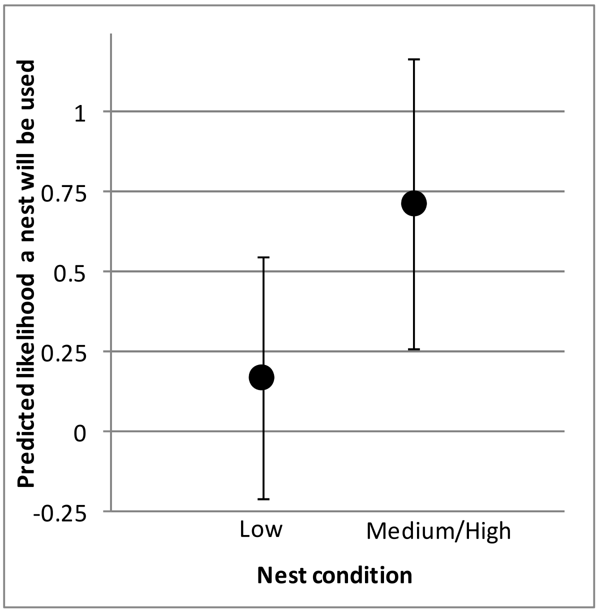

Figure 2.8 The predicted likelihood a nest was used in relation to condition of the nest observed after the breeding season. The circle represents the mean prediction and the dashes are one standard deviation around the prediction.

2.3.4.2 Success:Failure

The presence of prey remains was the variable most strongly related to whether breeding was successful or not, explaining 28.6% of the variability in the data as determined by the GOF value (Table 2.12). Nests were more likely to have been successful if they had prey remains present (Table 2.13). Alternative models that either had slightly lower explanatory power or were unstable due to a lack of variability in the data included brown leaves and bleaching.

Table 2.12 The change in DIC value when the stated variables are removed from the final tree level success: failure model

Variable	DIC
Base	
Prey Remains	6.2

Table 2.13 The mean, standard deviation, 2.5th and 97.5th percentile values for the posterior distribution of the parameters in the final tree level success: failure model

Variable	Odds ratio	Mean	SD	2.5th	97.5th
Base	0.162	-1.820	0.862	-3.737	-0.346
Prey Remains	25.972	3.257	1.236	1.047	5.934

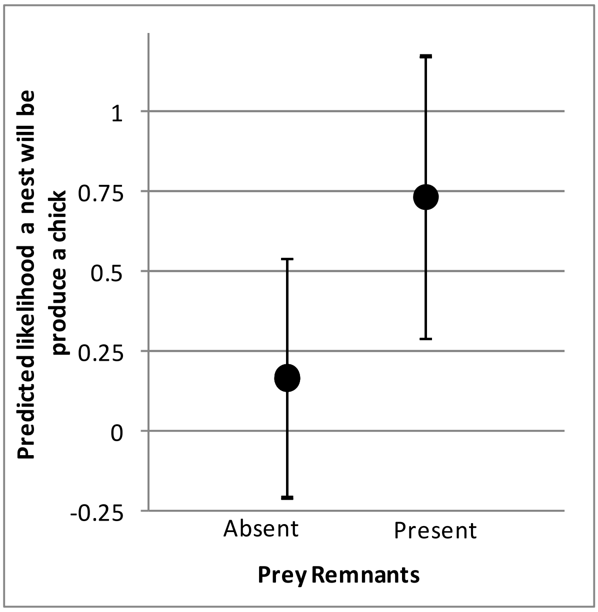

Figure 2.9 The predicted likelihood a nest was successful (produced a chick) in relation to the presence of prey remains observed after the breeding season. The circle represents the mean prediction and the dashes are one standard deviation around the prediction.

2.4 Discussion

2.4.1 Activity status of nests

Only 26% of the 84 nests examined in 2007–08 successfully produced a chick/fledgling. This low success rate was similar to that found in a number of other studies (Table 2.14). In particular it was similar to the proportion of successful nests reported for nests surveyed in Tasmania between 2000 and 2002 (Table 2.14). This low breeding rate may be partially explained by the fact that wedge-tailed eagles are known to have more than one nest within a particular territory, but only one is used for breeding in any one year. Given nests were selected randomly there is a high chance that the 'active' nest in the territory was not selected. Another explanation could be that some pairs do not breed every year because of extended post-fledgling dependence. Personnel observations by Brown and Wiersma note some degree of fledgling dependence at two different territories extends as long as three years, even in habitats appearing rich in prey.

Higher success rates have been found in other Tasmanian studies, with 60% of 11 nests in an undisturbed area successfully producing chicks (Mooney and Taylor 1996). It has also been reported that nesting success can decrease in disturbed areas (Mooney and Holdsworth 1991). The proportion of successful nests in the current study was slightly lower in areas subject to current wedge-tailed eagle nest management prescriptions compared with nests in less disturbed areas (semi-natural). Although this difference was not significant, further study is required to determine whether this is a result of the currently limited sampling effort. A larger data set with clearly defined levels of disturbance is required to explore this trend further.

Table 2.14 Summary of nest success rates for the Tasmanian wedge-tailed eagle from this study and other published data

Source of data	Year of study	Description of nest location	Number of nests assessed	Nest success rate %	Chicks/nest
Mooney and Holdsworth (1991)	1989	Disturbed[1]	19	43	0.43
		Little disturbed[2]	11	84	0.84
Mooney and Taylor (1996)	1996	-	11	60	0.60
State of the Forests Report (Forest Practices Authority, 2007)	2000	-	206	27.7	0.27
	2001	-	127	22.04	0.22
	2002	-	72	20.8	0.20
	2003	-	67	4.47	0.04
	2004	-	92	19.5	0.19
	2005	-	209	10.05	0.10
Mooney and Brown, unpublished data reported in Brown vs Forestry Tasmania, Federal Court of Australia, 2005	2000	Disturbed	129	23.3	0.23
		Little Disturbed	43	39.5	0.39
	2001	Disturbed	93	14	0.14
		Little Disturbed	27	51.9	0.51
This study	2007	Disturbed [3]	49	20.4	0.20
		Little Disturbed	35	34.3	0.34

[1] clearfell/clearing, partial harvest, roading/quarrying, intensive farming, intensive recreation, directed disturbance, [2] non-intensive farming and non-intensive recreation, [3] called managed sites in this study, [4] called semi-natural sites in this study.

2.4.2 Relationship between site variables and breeding success

The results indicated that whether a nesting attempt was made was related to the presence and amount of both mature forest and roads. Both of these variables may be related to the foraging behaviour of eagles. However, the production of a chick was more related to the area harvested within 6 km of the nest, suggesting that disturbance may influence the final success of the breeding attempt. While the low explanatory power of all of these models indicates that there are other influencing factors, the current results provide new insight into eagle breeding activity (Table 2.15).

While wedge-tailed eagles are well adapted to soaring flight, they can also be slow and manoeuvrable as a result of having broad long wings, a long tail and feathers appearing as fingers at the tips of the wing providing aerofoils and a low wing loading (for a large eagle). The combination of flight adaptations allows wedge-tailed eagles to live and hunt in a wide range of habitats from rugged bushland to open plains (Olsen 2005). However, an eagle's size means take-off from the ground is clumsy and difficult in dense forests (Olsen 2005). While eagles often use soaring flight to find food, they also adopt ‘short-stay-perch-hunt’ behaviour, staying concealed in the forest when actively hunting, then ambushing prey close to forest edges. Therefore, while eagles are capable of hunting in thick dense forests, the ideal habitat for hunting is likely to be forest with small open pockets or corridors where they can remain concealed but still hunt visually.

Our results indicated that a nesting attempt was more likely to be made where there were no roads within 500 m of nests, but that where a road was present the likelihood of a nesting attempt increased with increasing amount of road in 500 m. The visual and noise disturbance from vehicles on roads has been shown to result in desertion when in close proximity to a nest (Mooney and Holdsworth 1991; Debus *et al.* 2007). In addition eagles can be killed on roads. However, the negative effects of roads may be reduced where they are located a substantial distance from nests and where a road network provides clearings where prey and carrion to be obtained. Mooney and Taylor (1996) report that some levels of habitat modification may aid in predation, since open forest is much easier to hunt in compared with closed forest. Roads in dense forest may create the structure of more open forest making prey more accessible compared to dense closed forests. Future analysis needs to consider the proximity of roads to nest sites and the associated but equally negative visual and noise impacts.

The results also found that a nesting attempt was less likely to be made in areas without any mature forest in the surrounding landscape. Yet where mature forest was present, an increase in amount of mature forest resulted in a decrease in the likelihood that a nesting attempt was made. Several other studies have reported increased use by eagles of forests containing a mature element (Mooney and Holdsworth 1991; Mooney and Taylor 1996; Olsen 2005). The amount of mature forest and the associated density of forest may affect the energetic costs of food supply where eagles are unable to fly through dense forests to hunt and transport prey. The current model doesn’t suggest a threshold level. Although plantation extent was not a factor found to be significantly related to success of a nest in this study, it may reduce the quality of foraging habitat within a territory by reducing both prey availability and hunting efficiency. Eagle requirements should be taken into account in the design and ongoing management of plantations within eagle territories.

The ultimate success of a nest in producing a chick appears to be related predominantly to the area harvested within a 6 km radius of the nest. It has been reported elsewhere that forestry related activities are likely to have a negative impact on eagles (Mooney and Taylor 1996; Debus *et al.* 2007; Fox *et al.* 2004). In addition to providing visual and noise disturbance forest harvesting can result in the loss of nesting habitat for wedge-tailed eagles. Fox *et al.* (2004) note that rotation lengths in harvested areas, particularly in wet forest, are too short to allow the development of nesting habitat within a coupe. Although the creation of regenerating stands through some harvesting methods may increase prey abundance, harvesting followed by conversion to agriculture or plantation potentially reduces prey supply and hunting success. Removal of traditional roost/perch sites used for hunting during the breeding season may change hunting regimes and affect fledgling survival although this has yet to be examined. The influence of the timing of harvesting events and associated activities within a territory also needs further investigation.

There are documented cases where eagles consistently produce offspring in small, disturbed nest reserves, including nests located in eagle reserves in Tasmanian production forests (Department of Primary Industries and Water 2007). Although only eight nests in the current study were located in patches smaller than 20 ha, two of the four nests in patches smaller than 10 ha successfully produced chicks. In many of the reported cases of birds using small patches, the nest site appears to have been chosen after the environmental changes have occurred. In a number of cases eagles have been reported to abandon nests established in large tracts of forest, due to forest harvesting disturbance, but are later found to have occupied smaller areas of forest where perceived levels of noise and visual disturbance are greater (Mooney and Wiersma pers.obs.). It is likely that the small patch is tolerated because there is no ongoing disturbance in the area. Nest desertion may occur again, however, if forest patch size or shape changes. Small eagle nest reserves have the potential to maintain breeding pairs if we gain a better understanding of how the degree, timing and rate of disturbance within an eagle territory affects breeding activity. Past studies have focussed mainly on the effects of disturbance activities close to a nest site rather than the effect of disturbance within a territory. The results of the current study suggest that the level of disturbance within a broader spatial scale and impacts on productivity of eagles should be considered rather than just relying on protective measures close to a particular nest. The aim should be to minimise the rate and extent of disturbance within a territory to ensure the ongoing success of particular pairs.

2.4.3 Tree variables and breeding success

At the tree level, this study found the best indication that a nest had been used was the condition of the nest, which is an assessment of nest structure. Loosely woven and collapsing nests indicate the nest was not used, while more intact nests suggest it was. Other variables that also potentially indicate use are the presence of brown leaves and an abundance of white wash. There was some indication that the location of the nest had some effect, but this was likely to have been influenced by the fact that only three nests (all successful) were located on a secondary branch. Similarly with the amount of canopy below the nest, all three sites with >10% canopy cover below the nest showed signs of use. Further study is required before the true importance of these variables can be assessed.

The presence of prey remains was the strongest predictor of whether a nest actually produced a chick, with brown leaves and bleaching potentially also having some explanatory power. Eagles are known to visit nests outside of the breeding season, where they may add sticks for display purposes. However they are not known to use a nest site as a butcher site unless it is associated with breeding. Consequently, prey will not be evident on the nest platform unless chicks are present or up until a short time after the breeding season once the chick has left the nest. Fledglings may use nest sites for a number of weeks after they fledge as camping sites, where adults may bring prey to them. After the chicks begin to roost away from nest sites, scavengers such as forest ravens will pirate the prey remains left at the unattended nest sites (Olsen 2005)

It should be emphasised that this study examined which variables influenced the ‘success’ of a site, not the variables that influence which sites will be selected for nest construction. This means that some variables that are known to influence nest site selection (e.g. site aspect) were not identified in the models developed. However, an examination of the sites supports the description of nest site selection, with almost half of the sites examined (48.8%) located on an easterly aspect. A further 29.3% of sites were on a southerly aspect, with only 3.7% of sites on a northerly aspect, 8.5% a westerly aspect and 9.8% classified as having no aspect because they were located on flat ground. The preference for easterly aspect is most likely the requirement for sites sheltered from the strong westerly winds in Tasmania and supports previous working describing nesting habitat of Tasmanian wedge-tailed eagles (Mooney and Holdsworth 1991; Mooney and Taylor 1996). The current description of nesting habitat in planning documents (e.g. (Forest Practices Authority 2008) derived from earlier work and expert opinion is ‘ *Nest trees are amongst the largest in a locality in sheltered positions on leeward slopes, between the lower and mid slopes and with the top of the tree usually lower than the ground level of the top of the ridge.’* (Mooney 1988; Mooney and Holdsworth 1991;

Mooney and Taylor 1996b; Olsen 1998; Mooney 2000; Threatened Species Section 2006; Fox *et al.* 2004).

Table 2.15 Summary of outcomes from Bayesian logistic regression models.

Model	Model outcomes
Site level	
Use/non-use*[1]	• While nests were more likely to be used if there was no road in an area, if road was present, the likelihood that a nesting attempt was made increased with the amount of road in an area. • The absence of Mature Forest within 6000 m of a nesting site coincided with reduced breeding success, but where mature forest was present, an increase corresponded to a decrease in breeding success.
Success/failure*[2]	• An increase in the area harvested in a 6 km radius around the nest corresponded to a decreased likelihood that a chick was successfully raised.
Tree level	
Use/non-use*[1]	• An increase in nest condition (subjective measure of nest quality, Table 2.3) was the best way of assessing whether a nest had been used by an eagle in the previous breeding season.
Success/failure*[2]	• The presence of prey remains was the variable most strongly related to whether a chick had been raised at a nest the previous breeding season.

*[1]Nesting attempt or not (categories 1 & 2/ 0, Table 2.1)

*[2] Breeding attempt successful (category 2/ 0 & 1, Table 2.1)

Chapter 3
Determining nest site success using indirect signs

3.1 Introduction

There are a variety of different techniques used to gather information in order to define use of particular nest sites and subsequent breeding success. Direct measurable signs of nest activity commonly consider the presence of incubating adults or the production of a chick. There are two periods in the breeding season when such nest occupancy assessments can be conducted with minimal disturbance by trained individuals (Mooney and Holdsworth 1991). The first of these is the incubation period during September. However, determining whether or not an adult is incubating is difficult unless an egg is clearly visible, or adults are noted in an incubation pose over two weeks. The second period is during late November or early October, when nestlings are about 4–6 weeks of age and are large enough that with their white down they can be clearly seen from an aircraft or from a good vantage point with a spotting scope.

However, directly observing an egg or a chick in the nest is often difficult. Nest site characteristics (e.g. whitewash, green leaves) have, therefore, also been used when assessing the use and breeding success of a nest site. Using such indirect signs to determine the status of a nest means data can be collected after chicks have fledged, thereby minimising disturbance to the birds. Indirect signs have been used extensively by forest planners in Tasmania undertaking nest activity checks during the early and mid part of the breeding season (second week of September and November). However, the degree to which such indirect signs can be used reliably to determine nest site success has not been evaluated.

This study evaluates the degree to which indirect signs can be used to reliably determine nest site success (i.e. the production of a chick) for use in nest monitoring (post breeding season) and in nest 'activity checks' carried out by forest planners during the breeding season.

3.2 Methods

3.2.1. Nest site activity status

The activity status of the nests used in this part of the study was determined during aerial surveys (methods outlined in chapter two) or ground surveys conducted during the breeding season (November 2007). Each nest was determined to be either 'successful' or 'unsuccessful'. Successful nests were those containing a chick six weeks or older or where significant amounts of down was present around the nest (see Table 2.1). Unsuccessful nests were those classified as 'not used' or 'maintained' (Table 2.1).

3.2.2 Nest site surveys

Information on nest characteristics was collected from two separate sources which will be considered separately. Eagle specialists surveyed 42 nests in May and June 2008 either by helicopter or from the ground (Figure 3.1). These nests were selected opportunistically according to other work requirements from the 106 nests considered in chapter two. A further 54 nests were surveyed by forest planners between December 2007 and January 2008 as part of routine nest monitoring (Figure 3.1).

The nest characteristics assessed during post-breeding surveys are detailed in Table 3.1. The information collected by the planners was that required by the Threatened Species Section (DPIW) to assist with decisions on nest occupancy during the breeding season. However, not all variables were assessed at each site by forest planners.

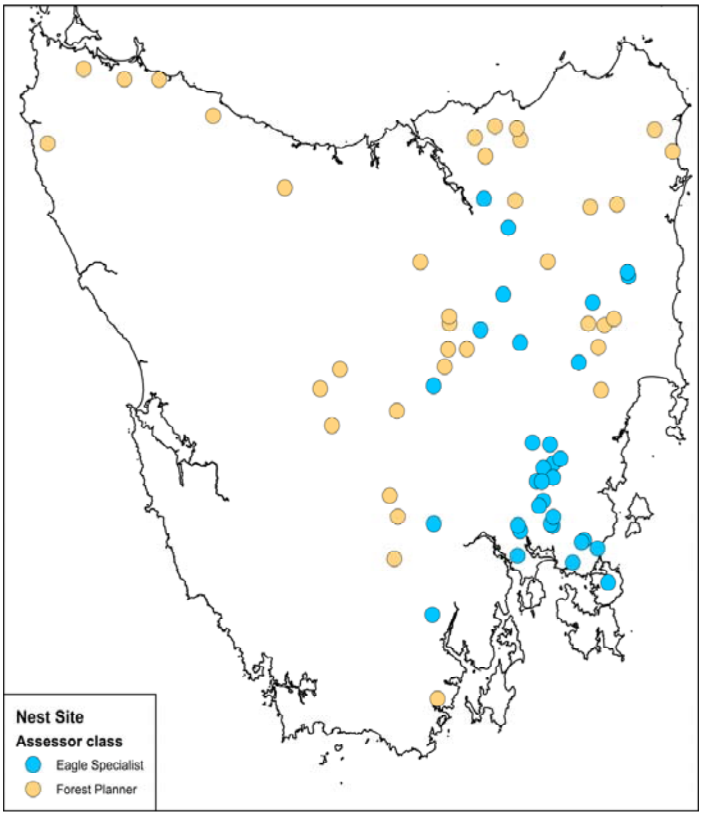

Figure 3.1 Location of nest sites surveyed by forest planners and eagle specialists.

Table 3.1 Nest characteristics surveyed, with an indication of whether they were collected by eagle specialists and forest planners, and from aerial surveys as well as ground surveys

Nest characteristics	**Observation method**	**Details**
Adult(s) Present	AG†Ω	Adult(s) seen at nest site or in close proximity.
White-wash	AG†Ω	The occurrence of excrement at the nest site.
Down	AG†Ω	White fluffy down from chicks or adults can be noticed on or around the nest, particularly during the later development of fledglings.
Prey remains	AG†Ω	Remains of prey at the nest may be viewed as old carcass frames or freshly delivered items. Flies and wasps may provide visual clues of items present.
Fresh green leaves	AG†Ω	Fresh green eucalypt leaves visible in the nest bowl.
Fresh brown sticks	AG†Ω	Recently added brown sticks (defined by lack of ultra-violet bleaching) visible in the nest.

Nest characteristics	Observation method	Details
Nest condition	AG†Ω	A subjective assessment of nest condition based on morphology. Low: Nest loosely woven and collapsing; Medium: nest showing some signs of collapse but is largely intact and compact; High: Structurally intact and compact.
Brown leaves	AG†Ω	Brown leaves containing tannin are visible, indicating that green leaves were present during the breeding season.
Pellets	G Ω	Pellets (regurgitated roughage containing fur/feathers and bone) observed on ground or in nest.
Bleached sticks	AG Ω	Amount of grey sticks bleaching (result of extensive sun bleaching and no recent fresh stick refurbishment). Measured in 1/3, 2/3, 3/3 of whole nest.
Leaching	AG Ω	Green leaching visible at nest base. Leaching is the result of phosphates deposited through excrement and bacteria leaching through the nest and onto the surrounding limbs below the nest structure.
Egg	G Ω	Egg and/or egg fragments visible on the ground or in the nest.
Nest width	AG Ω	The estimated width of the nest (cm) at the widest point.
Nest depth	AG Ω	The estimated depth of the nest (cm) at the deepest point.
Flat top	AG Ω*	The occurrence of compaction of the nest rim. This occurs when chicks walk on top of the nest during the late fledgling stage.
Nest bowl	AG Ω	A presence of a definite rim on the top side of the nest. This is generally more obvious in the earlier stages of the breeding period or at nests maintained but not used.

† – collected by forest industry planners during annual nest checks as part of operation planning

* – derived from photos of nests surveyed by forest planners

Ω – collected by eagle biologists from TSS and FPA as part of forest practices assessment and monitoring system

G – collected during ground-based surveys

A – collected during aerial surveys

3.2.3 Data Analysis

To determine the reliability of observed nest characteristics as indicators of nest success, the relationship between nest characteristics collected from either ground or aerial observations (Table 3.1) and the success of the nest was analysed using classification tree models. One of the advantages of using classification trees is that they readily deal with missing data. In addition to this they easily assess both categorical and continuous predictor variables and interactions between variables and are robust to outliers in the data. For the current study, data collected by eagle biologists and forest industry planners were analysed separately (Table 3.1) since eight of the nest characteristic fields were not gathered by forest planners. classification trees were constructed using the 'mvpart' package (Therneau *et al.* 2006) in the statistical program R (version 2.7.0) (Team, 2006). A maximal tree was constructed and cross validation error was used to determine the optimal tree size used in the final model (D'eath and Fabricius 2000). Alternate primary and surrogate splits were examined and the final model was selected as that with the lowest missclassification rate of those trees comprised of sensible ecological pathways.

3.3. Results

3.3.1 Nest site success

Of the 42 nests surveyed by eagle specialists, 13 were successful and 29 were unsuccessful. Of the 54 nests surveyed by the forest planners, 26 were successful and 28 were unsuccessful.

The number of nests in each category (successful and unsuccessful) with records for each nest characteristic is presented in Table 3.2 and 3.3. Many of the nest characteristics were observed at both successful and unsuccessful nests. Eagle specialists observed a high proportion of successful nests with brown leaves, white wash, prey remains. The majority of successful nests were also deep and wide, with flat tops and in good condition. However, a smaller, but still high proportion of unsuccessful nests also had brown leaves, were deep and wide. However, unused nests were more bleached (Table 3.2). Forest planner data confirms the frequent occurrence of fresh brown sticks and white wash in successful sites, but that both can also frequently occur in unsuccessful nests (Table 3.3).

It should be noted that many of the nest characteristics are likely to change over time and so their usefulness as predictors of nest success depends on when they are assessed in relation to the breeding season.

Table 3.2 Number of variables recorded at nests surveyed by eagle specialists

Variable	Number of successful nests surveyed	Number of successful nests with variable present	% of successful nests with variable present	Number of unsuccessful nests surveyed	Number of unsuccessful nests with variable present	% of unsuccessful nests with variable present
Green Leaves	13	1	7.69	29	3	10.3
Brown Leaves	13	10	76.9	29	15	51.7
Fresh Brown Sticks	13	4	30.8	29	7	24.1
White Wash	13	12	92.3	29	8	27.6
Down	13	1	7.69	29	0	0
Prey remains	13	6	46.1	29	2	6.9
Pellets	13	5	38.4	29	2	6.9
Partially bleached sticks	13	0	0	29	16	55.2
All bleached sticks	13	0	0	29	7	24.1
Nest Decomposition	13	0	0	29	7	24.1
Leaching	13	0	0	29	1	3.4
Egg/Egg Shell	13	1	7.69	29	0	0
Adult	13	1	7.69	29	1	3.4

Variable	Number of successful nests surveyed	Number of successful nests with variable present	% of successful nests with variable present	Number of unsuccessful nests surveyed	Number of unsuccessful nests with variable present	% of unsuccessful nests with variable present
Compressed Flat Top	13	12	92.3	29	3	10.3
Degrading Nest Platform	13	0	0	29	1	3.4
Nest Bowl	13	0	0	29	14	48.2
Nest Condition						
Good	13	9	69.2	27	13	48.1
Average		4	30.7		4	14.8
Poor		0	0		10	37.0

Note – successful nests were those containing a chick six weeks or age or older. Nests were also classified successful where chicks were not observed late season but large quantities of down and white-wash were present around the nest. Unsuccessful nests were classified as ‘not used’ or ‘maintained’ (Table 2.1).

Table 3.3 Number of variables recorded at nests surveyed by forest planners

Variable	Number of successful nests surveyed	Number of successful nests with variable present	% of successful nests with variable present	Number of unsuccessful nests surveyed	Number of unsuccessful nests with variable present	% of unsuccessful nests with variable present
Green Leaves	21	10	47.6	17	1	5.8
Brown Leaves	21	3	14.3	17	2	11.8
Fresh Brown Sticks	21	17	80.9	17	11	64.7
White Wash	21	19	90.4	17	8	47.0
Down	21	2	9.5	17	0	0
Prey remains	21	2	9.5	17	1	5.8
Adult	21	2	9.5	17	3	17.6
Nest Condition						
Good	18	18	100	17	12	85.7
Average	18	0	0	14	2	14.3
Poor	18	0	0		0	

Note - successful nests were those containing a chick six weeks of age or older nests were also classified successful where chicks were not observed late season but large quantities of down and white-wash were present around the nest. Unsuccessful nests were classified as 'not used' or 'maintained' (Table 2.1).

3.3.2 Classification tree analysis – eagle specialist data

The nest characteristic assessed by eagle specialists found to be most strongly associated with the production of a chick in a nest was the presence of a compressed flat top (Figure 3.2). The presence of a flat top was the only branch in the model which correctly predicted 89.7% of unsuccessful nests and 92.3% of successful nests (Table 3.4). No alternative models were similar in predictive ability.

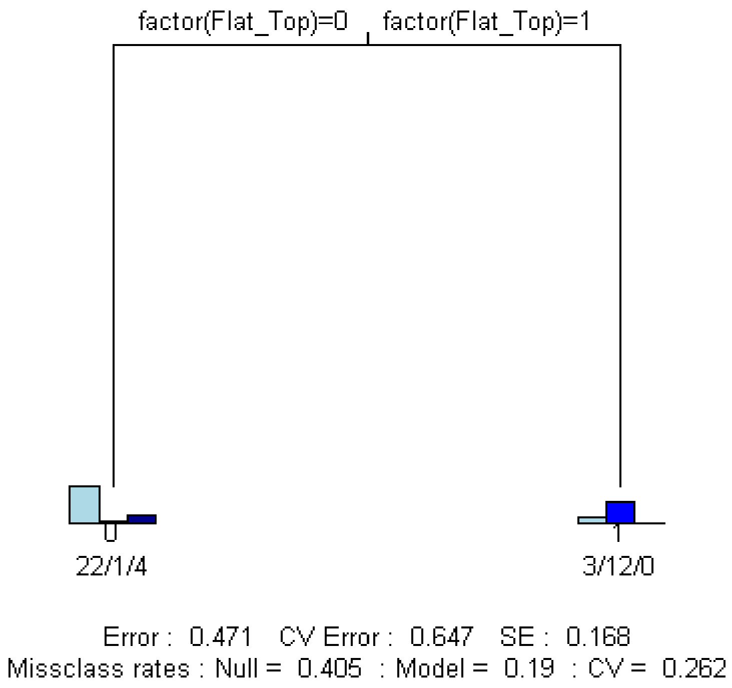

Figure 3.2 The final classification tree using eagle specialist data that explores the relationship between nest attributes and whether a nest produced a chick in the previous breeding season.

The vertical length of the branch represents the relative strength of the split. The one or zero at the end of each branch represents nests were predominantly successful (1) or not (0). The numbers below that represent the number of samples in the current data set that were found at that leaf, where the number on the left side of the slash is the number of samples in which nests were not successful and the number on the right is the number of nests in which a chick was produced. For the missclass rates, the null rate is the error when the rule 'go with the majority' is used. The model rate is the missclassification rate found from using the stated model. Error represents the overall missclassification of the model, CV Error is the cross-validation error and SE is the standard error of the model.

Table 3.4 Results of using the presence of a flat top to assess whether a nest produced a chick in the previous breeding season, using eagle specialist data

Observed	**Predicted**	
	Unsuccessful	Successful
Unsuccessful	26	3
Successful	1	12

3.3.3 Classification tree analysis – forest planner data

The initial model produced using forest planners found white wash to be the best predictor that a nest had been used. Using this model, 95.2% of successful sites were predicted correctly, but only 47% of unsuccessful sites. Alternative splits for this model were either the presence of green leaves, or the presence of a flat top. However, both of these variables had large amounts of data missing (i.e. it wasn't always collected by forest planners). We made the assumption that forest planners would have recorded green leaves or a flat top if they were visible and reclassified all missing data for these two variables as 'absent'. Reanalysis of the modified data set found the occurrence of a flat top as the primary explanatory variable (Figure 3.3). Using this model, 88.2% of unsuccessful sites were predicted correctly, but only 61.9% of successful sites (Table 3.5). White wash and green leaves remained comparable models.

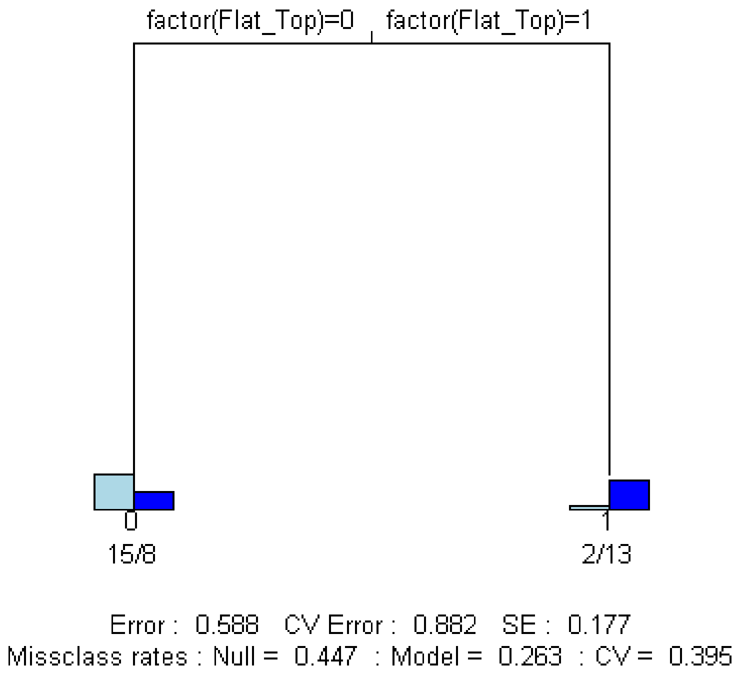

Figure 3.3 The final classification tree exploring the relationship between nest attributes and whether a nest produced a chick in the previous breeding season, using forest planner data. For an explanation on interpretation of this figure, refer to Figure 3.2

Table 3.5 Results of using the presence of a flat top and the presence of green leaves to assess whether a nest produced a chick in the previous breeding season, using forest planner data.

Observed	**Predicted**	
	Unsuccessful	Successful
Unsuccessful	15	2
Successful	8	13

3.4 Discussion

3.4.1 Value of indirect signs in predicting the activity status of wedge-tailed eagle nests'

The results of this study indicate that some indirect signs can be used to evaluate the activity status of wedge-tailed eagle nests. In particular, the presence of a compressed flat top (Figure 3.4) was a good predictor.

Figure 3.4 A Tasmanian wedge-tailed eagle nest, photographed from a helicopter during June 2008, showing the distinctive flat top and lack of nest bowl. This feature is common where fledglings have been produced. (Photograph by DPIW)

A flat top is generally produced when chicks walk on top of the nest during the late fledgling stage. However, it should be noted that while the presence of a flat top at a nest provides some level of certainty that a chick was produced, the occurrence of a flat top does not guarantee the chick fledged, i.e. chicks may die or be killed just prior to fledging. The time taken for chicks to compress flat tops is not known. A flat top to a nest should be regarded as reflecting the production of a chick, but not necessarily the chick fledging until this is established by further research.

The initial variable identified as important for establishing breeding success when using forest planner data was the occurrence of white wash (faecal matter). Yet, while more than 90% of the successful nests assessed by eagle specialists were observed with white wash, this variable was not identified during the modelling process as being important because almost 30% of unsuccessful nests also had white wash. White wash can accumulate below a nest or underneath limbs when a site is being used for roosting or as a display platform rather than being used as a breeding site. This means that the presence of white-wash should not be used as the only predictor to determine nest success.

Another variable identified as a potential predictor of nest success by the forest planner data was the presence of green leaves (Figure 3.5).

Figure 3.5 Tasmanian wedge-tailed eagle nest with fledgling, showing the characteristic green leaves, white-wash and new materials added by adults. (Photograph by Leigh A Walters, Tasmanian Land Conservancy)

Green leaves were not identified as an important predictor in the eagle specialist model because very few nests surveyed had green leaves. This is almost certainly because the eagle specialist surveys were done later in the year than forest planners, well after the breeding season. Green leaves are primarily observed in nests because they are used by eagles to line their nests. As the season progresses the leaves desiccate and turn brown. This highlights the importance of timing when assessing the variables that are important to monitor. However, green leaves in a nest may also be the result of leaves being blown into the nest by strong winds rather than nest lining activity. Furthermore, in common with the genus, a breeding pair may line several nests in their territory with green leaves (Wiersma, Mooney and Brown pers. obs.).

Many of the variables considered in this study are likely to change over time, which means the predictive ability of variables will depend on when the data is collected. How they change depends on whether they are related to nest building or chick rearing, and how far into the breeding process the survey is done. For example, observations of a flat top to a nest may be most useful in post-breeding season (April–June) monitoring since this feature develops from the movement of chicks during the late fledgling stage. Flat tops to nests observed earlier, during the breeding season, may just be a result of nest use in the previous season. However, it is possible to distinguish previous season nests because nest platforms become bleached if no new material is added. Flat tops on bleached nests are most likely a result of the previous breeding season. Flat tops that are brown in colour are more likely to indicate recent nesting activity.

Assessing a combination of variables may increase the certainty of a nest activity assessment. The presence of white wash alone suggests recent eagle activity, but it is not a definite indication that this is breeding activity. However, the presence of white wash in combination with green leaves and a flat top to the nest may be a stronger indicator that breeding activity is occurring. Prey remains, while less common until the later part of the season, may also be indicator of use (see chapter two). Observation of a flat top, abundant whitewash and prey remains during post-breeding monitoring surveys would indicate a high probability that a nest produced a chick in the previous breeding season. Nest attributes indicating breeding activity that are more likely to be observed during the breeding season (when it is difficult to observe a chick directly) may be a combination of green leaves, a flat top and abundant white wash. Therefore an understanding of eagle nesting behaviour as well as consideration of the timing of surveys is required when identifying variables useful for monitoring the success of eagle breeding activity. Further research is required to identify variables that can be used early in the breeding season to predict the use of a particular nest.

Chapter 4 Conclusions and future work

4.1 Nest success and site variables

Despite the short-term and small sample size of the current study, a number of important results have been identified. This study contributes to the small amount of information available on rates of nest success in Tasmanian wedge-tailed eagles. It was shown that a large proportion of nests are not used in any given year and that not all nests with an eagle attending produce a chick. The habitat available in the territory around the nest appears to influence the use of a nest by eagles, but disturbance from harvesting in the territory appears to affect breeding success. It was shown that nest success was slightly lower in areas subject to forestry activities (where current management prescriptions apply) compared to areas with little forestry activity, although this result was not significant. However, the ability for eagles to use small habitat patches and the relationship with mature forest documented in the current study indicates that eagles do not strictly require large tracts of mature forest in order to breed successfully. Therefore the potential exists for production forestry to occur within an eagle's territory without unduly affecting breeding success, if the activity is managed appropriately. The current nest reserves and 500 m, 1 km line of sight breeding season exclusion zones are an important first step in this management process.

However, this study suggests that it is important to consider disturbance to eagles at a broader scale than currently occurs. Further work is required to understand exactly how harvesting activities (rate and extent) within a territory disturb eagle breeding activity, in order to facilitate the production of appropriate management procedures. Additional protective measures at particular nest sites may need to be considered to ameliorate the broader territory impacts. Monitoring of the established nest sites over the medium to long term is required to better understand the trends reported in this first year of the study. Successive years' data would allow the impact of landscape changes within eagle territories and specific land use activities to be better evaluated.

4.2 Value of indirect signs – what to observe when assessing the activity status of a nest

The results reported in chapters two and three can assist with decisions on the activity status of a particular nest both during the breeding season and in post-season monitoring. The presence of a chick at the nest is obviously the most important indicator of the activity status of a nest. However, when this is difficult to observe the attributes summarised below may be useful. Training of observers is required, however, to ensure that these nest characteristics are adequately assessed and reported. This is particularly important for the more subjective measures, such as nest condition and flat top. Further work is required to determine the attributes most important to monitor prior to the breeding season.

Attributes most useful during the middle of the breeding season (September–October) are:

- flat top
- green leaves
- white wash.

Attributes most useful late in the breeding season (November–January) are:

- flat top

- green and brown leaves
- white wash
- prey remains.

Attributes most useful after the breeding season (March-May) are:

- flat top
- brown leaves
- white wash.

4.3 Timing of the breeding season

Surveys conducted during this study suggest that there are many birds now breeding outside the August to January core breeding period originally noted by Mooney and Taylor in 1996. Some birds were found lining nests as early as April and some eagles were incubating as early as late July while others began in late September. Although Mooney and Holdsworth (1991) and Mooney and Taylor (1996) recognised the core breeding period as starting in August, they also note that birds commonly begin refurbishment work a couple of months prior to incubating. Both early and late breeding pairs were encountered in this study.

This increased variability in the timing of breeding is of concern since application of the nest management provisions only during the currently recognised core breeding period (August to January inclusive) will not cater for the increasing number of individual pairs that breed early or fledge young late in the season (see figure 1.0). While changing the length and timing of the season has implications for planning of forestry operations, adults from nests that are disturbed during early incubation or late in the season may desert and move to an alternative site transferring the problem to another area.

4.4 Limitations of this study and future work

This study established sites and methods for the long-term monitoring of eagle nests to evaluate the effectiveness of current management measures applied to activities covered by the Tasmanian forest practices system. Some problems were encountered during the development of the methods and these need to be taken into account in future work.

It was only possible to examine the relationship between nest site success and disturbance variables at a very coarse scale in this first year of the study. The number of sites needs to be increased in future years, in particular more sites located in small patches of forest (<10ha) and more detail of land use within immediate areas surrounding nest sites and within the territory is required. The GIS data used to assess the relationship between nest site success and site level variables was very coarse. For example, in some cases browsing management data contained detailed accounts of work conducted near nest, accurately describing dates, while other datum contained broad category details. All data were transformed into an activity relating to browsing control rather than specific types and timing of works conducted. The transformation of these data reduced the ability to test the potential impact of a particular management activity. A second example was the lack of detail relating to different harvesting methods and their affect. Future study should consider investigating the use of GPS and satellite tracking methods to study the impact of different forestry activities on breeding pairs.

Two main errors occurred when locating nests using fixed wing aircraft. The first was error in locating the position of the nest due to the slow update speed of the GPS unit. While a touch screen laptop was used to view topographic features and the placement of nests on the live GIS system, it was easy to mistake nearby nests in the same territory as the target nest, thereby recording an incorrect results for the target nest. GPS units update on average once every second. The slow refresh rate means that the observer has to take into account the distance travelled in order to establish which nest is being viewed. Track logs provide an essential method for evaluating the path flown to alleviate many of the issues associated with slow refresh rates. Figure 4.1 shows a typical scenario where track log defines the path flown.

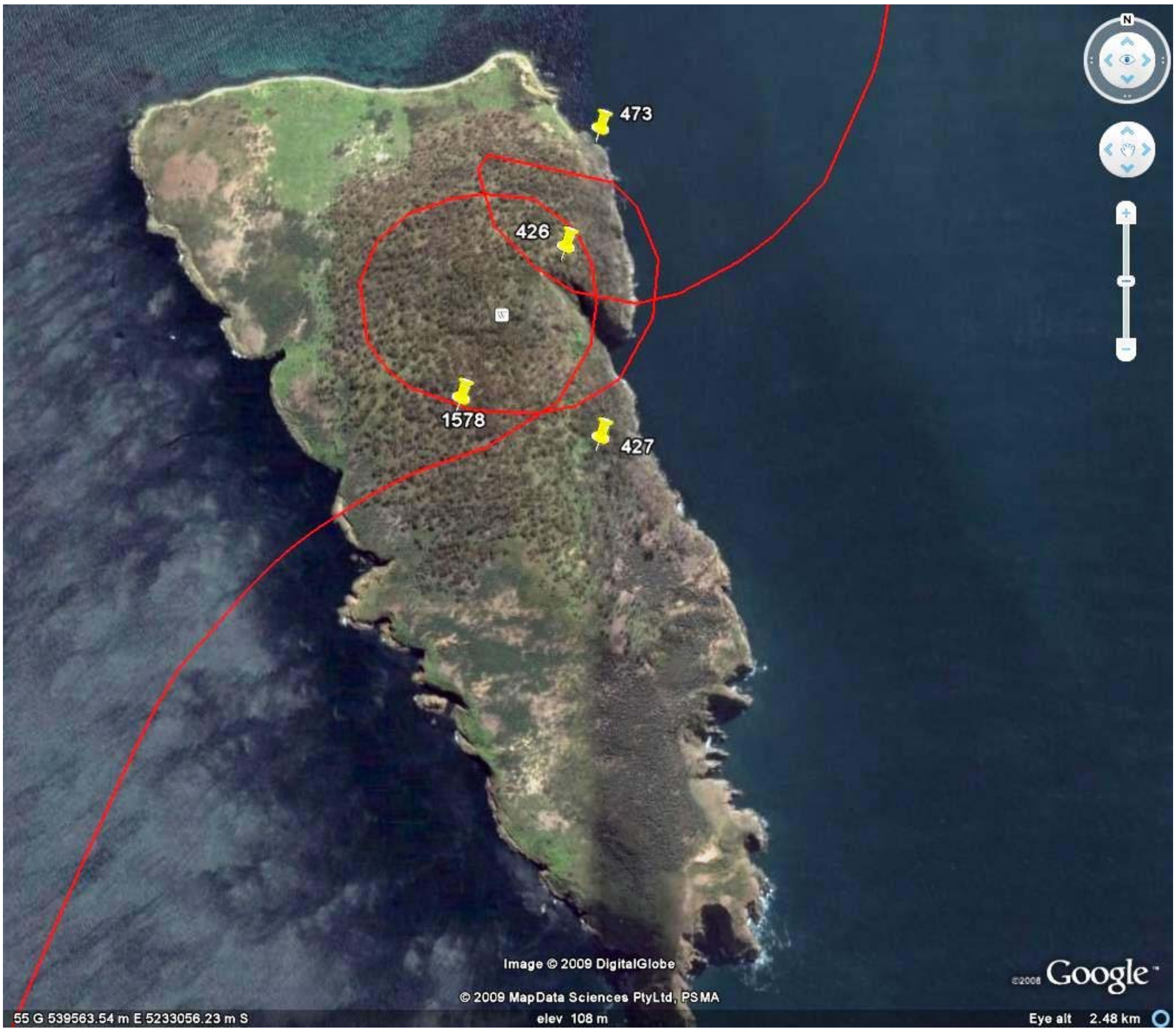

Fig 4.1 Track log from survey work conducted in a fixed wing Cessna 206 F at Betsy Island, showing target and non target nests surveyed. The red line indicates the track log of the path flown.

Initial interrogation of GPS based co-ordinates revealed significant error among nest site co-ordinates. A number of nests were more than one hundred metres out due to: (1) an inferred nest position being provided through terrain interpretation/interpolation; (2) less accurate GPS software and lower quality patch antenna bases (Quadrifilar Helix antennas provide better coverage and accuracy); and (3) incorrect data entry.

Due to the analyses being based on nest position, nest site accuracy was limited to +/- 30 meters, using nest site visits and detailed knowledge of nest sites to correct large errors. The potential influences of large GPS co-ordinate error are significant when considering small radii. However the large radii investigated in this study (500 m, 1000 m and 6000 m) reduced the effect of poor GPS positioning.

Work conducted during the 2007–08 season allowed a cost-benefit assessment to be conducted to evaluate cost of assessing productivity using various data collection techniques such as helicopter, fixed wing aircraft and ground nest surveys techniques. The outcomes are provided in Appendix E.

Recommendations for future work include:

- Continue monitoring of the 84 nest sites established in this study and additional new nest sites added in subsequent years. Increase the number of activity checks by specialists to enable an assessment of nest failure (egg laid but no chick) and production of a fledgling. More frequent nest checks will also enable the timing of breeding to be better evaluated.
- Design a study to look specifically at type and nature of disturbance and impact on breeding pairs and their offspring resulting from different forestry activities.
- Design a study to look at foraging behaviour and range by a breeding pair of eagles. There is sufficient technology available to investigate 'animal movement' with the advent of satellite and GPS technologies. The employment of such technology has been used successfully in the past to ascertain habitat with other related species (Meyburg and Fuller 2007). An analysis of foraging behaviour for breeding pairs in close proximity to intensive forestry would provide detailed information to better manage territories.
- Investigate the influence of forest patch size on nesting success. This was not possible in this study as the majority of nests were in patches >20ha.
- Further evaluate aspect and tree level factors to provide an updated model to predict wedge-tailed eagle nesting habitat.
- Develop actions/recommendations to improve management of nest sites in areas subject to activities covered by the forest practices system.
- Improve the nest activity tracking system within FPA.
- Train forest planners in the identification of indirect signs.
- Develop an expert-based system to increase efficiencies during decision making processes while also providing a more up-to-date database and feedback system for FPOs. A proposal for such a system is provided in Appendix F.

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Appendix A
Summary of the activities to meeting the requirements of the funding agreement with Roaring 40s

Activity	Milestone (Underlined where also an output).	Achievement Indicator	Progress
Review information on impact of forest disturbance on wedge-tailed eagles and development of current management measures in ‘off-reserve’ areas	Literature reviewed	Review complete and endnote database prepared	EndNote database completed in September 2007. Summary of review incorporated into final report for 2007–08 season.
Complete the monitoring of the implementation of eagle nest management prescriptions for 1997–98 and 2001–02 plans	Analyse the data collected and summarise for report	Relevant report chapter completed	Ongoing monitoring of 2001–02 implementation/results will be provided in the 2008–09 report.
Assessment of available data	Established the suitability of remotely available data (GIS layers for disturbance, forest type, reserve area etc.)	Data requirements established	Difficulties encountered in site selection and access to GIS data delayed the assessment of available data until October 2007 – this is now complete.
Develop statistical design for project	Develop design and approach to analysis of data	Statistical design and analysis methods defined	The development of the statistical design was mostly achieved by October 2007. Small adjustments were made in collaboration with the consultant Statistical Adviser.
Re-visit some of the nest sites observed over a five-year period by Mooney and Taylor (1996)	All sites surveyed and data summarised for report	Relevant report chapter completed	The majority of this part of the work was completed by November 2007. All available data gathered and consolidated during January 2009.
Selection of ten nest sites in the NE of the state in areas subject to forestry disturbance in the period 2001–2006 (10 disturbed sites)	Selection of ten nest sites from database	Sites selected and locality confirmed	This has been completed. The number of nest sites chosen was increased from the original estimate due to statistical reasons. Further funding enabled aerial surveys.
Selection of ten ‘control’ nest sites in reserved areas in the NE of the state (10 control sites)	Selection of ten ‘control’ nest sites from known nest database or through survey of potential habitat	Sites selected and locality confirmed	Work completed on time according to schedule. The number of nest sites was increased from the original estimate due to

Activity	Milestone (Underlined where also an output).	Achievement Indicator	Progress
			statistical reasons. Further funding enabled aerial surveys.
Activity observations of nest sites	All nest sites monitored for activity 3 times between July – February	Monitoring data entered	All observations were completed by ground and aerial observation by December 2007. 'Success' of nest sites surveyed in past years has been estimated using existing survey data and Bayesian networks.
Establish data variables that need to be collected on-site and methods of collection. Collection of tree and site level variables (including disturbance and protection measures) for each nest site.	Completion of environmental variable data collection	Environmental variable data collected and entered	Data variables were selected during November 2007 with the majority of field work to be completed out of the breeding season, during March–May 2008. This work remains in progress.
Data analysis	Completion of data analysis	Data analysed and summary graphs/tables prepared	Some delays due to delays in site selection, gathering of GIS data and availability of statistical advisor. Data analysis began during December 2007 and was completed in December 2008.
Collate results/information and produce a final report including detailed results of the project work and recommendations for future monitoring. Report will include any recommendations for changes to the conservation management actions for the maintenance of nesting habitat for the wedge-tailed eagle.	Complete Final Report	Final report and recommendations	Development of the first draft of the report will began in May 2008. Final draft completed Feb 2009 due to delays in data analysis.

Appendix B
Visibility modelling with PI data – an approach to determining '1 km line of sight' from a wedge-tailed eagle nest

October 2006

by Tim Leaman (Conservation Planner, Forestry Tasmania) & Peter von Minden (GIS Technical Officer, Forestry Tasmania)

Introduction

Wedge-tailed Eagle nest management prescriptions for forest practices at present are delivered through the Threatened Fauna Adviser and can be summarised in the following:

- Surround known nests with an undisturbed reserve of at least 10 ha.
- No forestry activities (including roading, harvesting, burning, carting, loading, boundary marking, planting, 1080 baiting etc.) are to be conducted within 500 m or 1 km line of sight of a nest during the breeding season (August–January inclusive). The reserve should not be approached on foot within 500 m unless directed by the FPB zoologist.
- No burning should be conducted within 500 m or 1 km if in line of sight of the nest during the breeding season (August–January inclusive). Use of helicopters in the vicinity of wedge tailed eagle nests during the breeding season is not advisable. High intensity regeneration burns should not be allowed to enter a wedge tailed eagle nest reserve at any time of the year. However, a low intensity burn for fuel reduction purposes may enter a wedge tailed eagle nest reserve outside the breeding season.

The development of these management prescriptions was guided largely by the work of Mooney & Holdsworth (1991) who identified 500 m as the critical distance at which heavy disturbance should be excluded during the breeding season. This critical distance was later broadened to include areas within 500 m or '1 km line of sight' (LOS) of a nest during the breeding season (Mooney, 2000).

The 'line of sight' concept is not new to the forest industry, however there has never been an agreed procedure for how it should be determined. There are various approaches available for determining line of sight (examples in Figure 1), however up until now most methods have failed to include a factor of vegetation. Failing to account for forest vegetation in the landscape delivers an unrealistic estimate of what might be visible from the viewpoint of an eagle nest (Figure 1, Model 1).

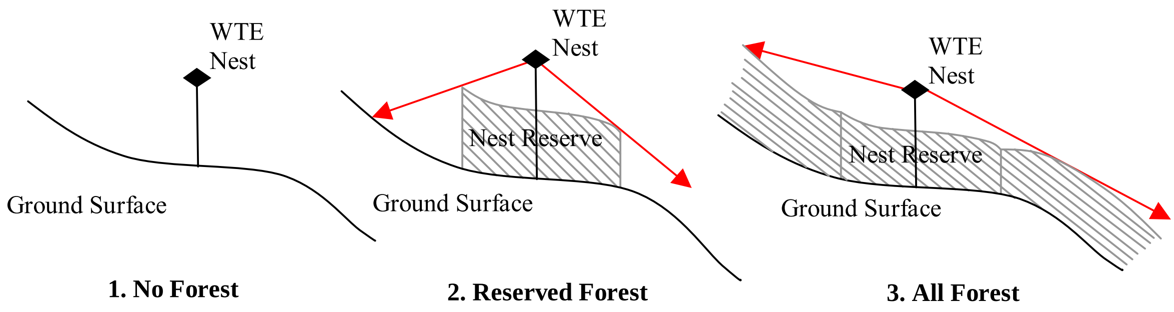

Figure B. 1 Three Models with different considerations of vegetation that can be used to determine line of sight. Model 1: no forest (Bare Ground Model); Model 2: reserved forest (Forested Reserves Model); Model 3: All Forest Model.

This project models how reserved forest affects the eagle's visibility from its nest. It uses twelve nests near ten coupes from Forestry Tasmania's Three Year Plan and compares the results of modelling with and without reserved vegetation (Compares Models 1 & 2, Figure 1). This project does not consider the application of the 'All Forest Model' (Model 3, Figure1).

Methods

Bare Ground Model (No forest)

1 The visible area was calculated using the ArcGIS 'viewshed' function with a nest height fixed at 30 m for each nest location. Note that the 25m Digital Elevation Model (DEM) was used as the z surface. The resultant model was labelled as the 'Bare Ground Model' (BGM).

Forested Reserves Model (Surrounding Reserved Forest)

2 Determined the height of each nest using the Pitype (Photo Interpreted) Vegetation layer. Where the vegetation stated that the height was within a range, the maximum height was used. Similarly, if there was more than one forest element, such as mature and regrowth, the maximum height was used, see Table I below.

Table B.1 Modelled nest heights based on maximum Pitype height

NEST #	EASTING	NORTHING	COUPE	PITYPE	HT_RANGES	NEST_HT
1425	542379	5410305	BS126D	co E2d.ER4d.s	41-55 m & 37-44 m	55 m
1256	355533	5468268	BV013B	E2b.ER	41-55 m	55 m
1366	492242	5232491	FN004D	E2d.S.T	41-55 m	55 m
1367	492306	5232304	FN004D	ER4c.TW.om E1f	37-44 m & 55-76 m	76 m
898	490970	5226930	FN026C	E2d.ER1(P).S.	41-55 m & <15m	55 m
1383	488583	5217884	KD009E	E1.d.S.T	55-76 m	76 m
795	565882	5225302	KY005E	ER4b.E2f	37-44 m & 41-55 m	55 m
1212	525490	5429367	LI129C	E2d.Tw.S	41-55 m	55 m
985	342112	5457184	NA020B	Tb.S.**	34-41 m & 27-37 m **	41 m
1165	512497	5446657	RT229D	E2d.S	41-55 m	55 m
1166	512141	5446776	RT229D	E2d.ER3f.S.T	41-55 m & 27-37 m	55 m
1046	313308	5459894	SR032A	E+3c.S.	34-41 m	41 m

**** Tb or Backwood has no recorded heights so the next closest Pitype was used being E+3c.ER3C.S., which was 37 m away.**

3 The next step was to clip out all the pitype data where there was an MDC reserve. The following rules were applied to determine the height of the vegetation;

Mature Eucalypt:

Height Classes 55-76m = 55m, 41-55m = 41m, 34-41m = 34m, 27-34m = 27m, 15-27m = 15m or <15m = 10m

Regrowth Eucalypt:

Height Classes >50m = 50m, 44-50m = 44m, 37-44m = 37m, 27-37m = 27m, 15-27m = 15m or <15m = 10m

Regeneration Eucalypt:

Height Classes >50m = 50m, 44-50m = 44m, 37-44m = 37m, 27-37m = 27m, 15-27m = 15m or <15m = 10m

Other Native Forest:

M+ = 30m, M- = 15m, Tw (Wattle) = 20m or T (Secondary Species such as Blackwood) = 20m

Everything Else:

0m

The PI density class 'f' (<5% mature canopy cover or 1–10% regrowth canopy cover) was excluded from the analysis as it was considered to not provide adequate screening to affect visibility.

4 With the Reserved MDC \ Pitype classified into heights, the next step was to convert the heights into a grid and add the grid to the 25m DEM to provide an adjusted surface elevation that takes into account the surrounding reserved vegetation.
5 Again using ArcGIS's function 'viewshed', the resultant model was labelled the 'Forested Reserve Model' (FRM).
6 Visual outputs of the model comparisons were plotted using the 'IntraGIS' software package (pg 4-13).

Results

Eight of the ten cases identified less area in total in the FRM while the remaining two cases (FN004D & NA020B) identified a greater area in the FRM (Table 2). In these last two cases there were no nest reserves in place at the time of this modelling work.

In the area between 500 m and 1 km LOS from the nest there were five cases that identified more area in the FRM and five cases that identified less area in the FRM (Table 2). A visual display of Table 2 is provided in pages 4–13 (visible area represented by red and green hatching).

Table B.2 Visible area identified by BGM against FRM

		BGM Visible (ha)		FRM Visible (ha)			Position of nest in landscape
Coupe	Nest #	Total	500 m to 1 km	Total	500 m to 1 km	500 m to 1 km Difference	
BS126D	1425	76.5	37.3	26.5	11.9	-25.4	Gully
BV013B	1256	228.6	157.7	135.1	108.3	-49.4	Near Ridgetop
FN004D	1366/1367	205.2	104.4	239.1	130.2	25.9	NA (no reserve)
FN026C	898	129.8	74.1	111.4	84.9	10.9	Midslope
KD009E	1383	199.2	22.6	138.9	24.0	1.4	Midslope
KY005E	795	202.1	134.4	155.0	110.3	-24.1	Gully
LI129C	1212	194.4	134.8	131.3	98.9	-35.9	Midslope
NA020B	985	138.8	80.8	152.4	91.5	10.8	NA (no reserve)
RT229D	1165/1166	335.1	98.7	159.3	99.6	0.9	Midslope
SR032A	1046	343.0	168.4	183.7	163.8	-4.6	Ridgetop

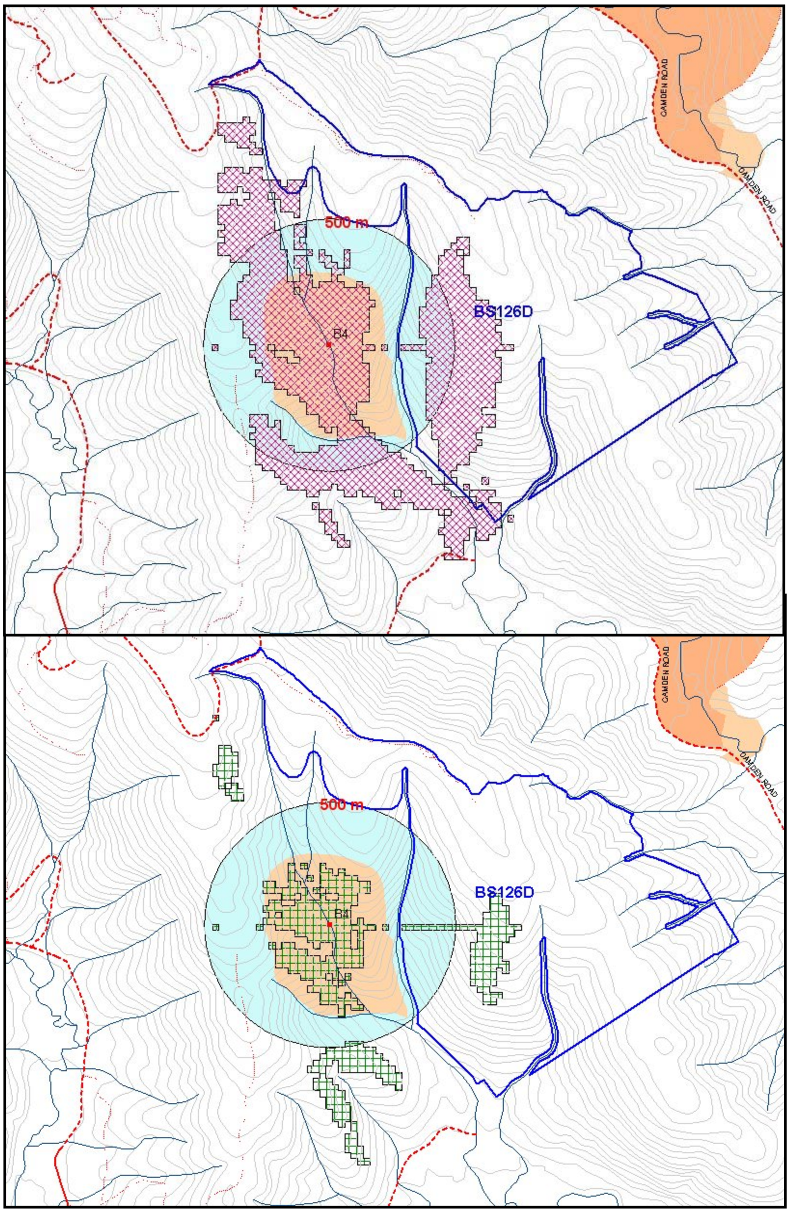

Figure B.2 BS126D Nest deep in a gully. Screening provided by nest reserve in all directions.

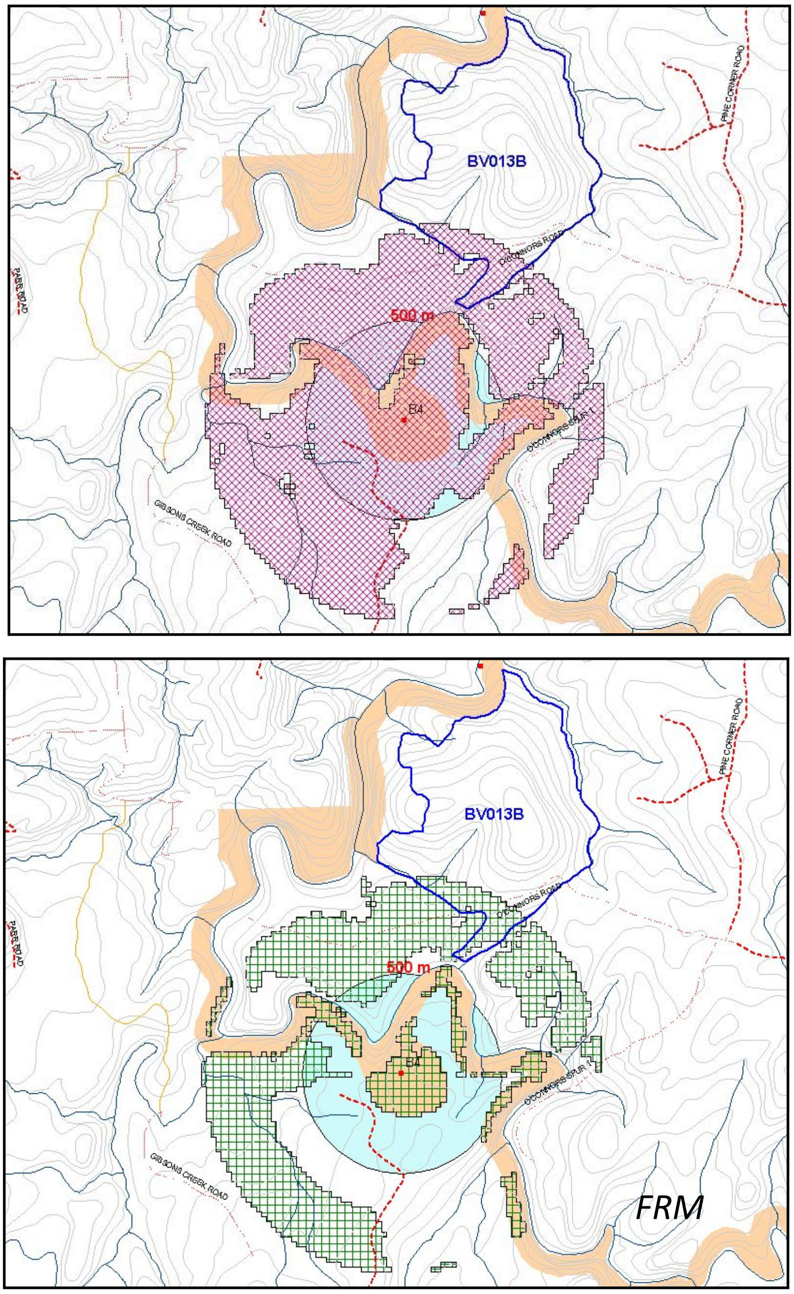

Figure B.3 BV013B Nest near ridgetop. Screening provided by nest reserve and wildlife habitat strip.

Appendix C
Nest data

Table C.1 Nest numbers and category of long-term wedge-tailed eagle study sites, co-ordinates omitted

NEST_I	Category	2004–05	2005–06	2006–07	2007–08	Use Category	Ran
91	Semi-nat				Successful	Successful	3
121	Managed				Not Used	Not Used	0
122	Managed				Not Used	Not Used	0
127	Semi-nat				Successful	Successful	3
128	Managed				Not Used	Not Used	0
203	Semi-nat				Not Used	Not Used	0
205	Semi-nat				Not Used	Not Used	0
211	Managed				Not Used	Not Used	0
233	Semi-nat				Used	Used	1
245	Semi-nat				Used	Used	1
294	Semi-nat				Not in use	Not Used	0
308	Semi-nat				Used	Used	1
328	Semi-nat				Successful	Successful	3
390	Semi-nat				Not Used	Not Used	0
426	Semi-nat				Not Used	Not Used	0
433	Semi-nat				Successful	Successful	3
470	Managed				Lined/Not used	Used	1
471	Semi-nat				Successful	Successful	3
495	Semi-nat				Not Used	Not Used	0
498	Semi-nat				Incubating	Used	1
503	Retro-s	Not	Not	Not		No Investment	0
504	Managed				Successful	Successful	3
506	Retro-s		Present	Present	Present	High investment	3
543	Retro-s	Not	Not	Not	Gone	No Investment	0
568	Retro-s	Not	Not	Present	Lined/Not used	Low Investment	1
570	Managed				Successful	Successful	3
571	Retro-s	Not	Not	Not	Not in use	No Investment	0
578	Retro-s		Present	Present	Present	High investment	3

NEST_I	Category	2004–05	2005–06	2006–07	2007–08	Use Category	Ran
591	Semi-nat				Indeterminate	Used	1
595	Managed				Incubating	Nesting Attempt	1
612	Managed				Not Used	Not Used	0
614	Managed				Not Used	Not Used	0
673	Retro-s		Not	Not	Not Present	No Investment	0
696	Semi-nat				Not Used	Not Used	0
697	Managed				Successful	Successful	3
753	Semi-nat				Suspect Chick	Used	1
756	Managed				Successful	Successful	3
763	Retro-s		Not	Not	Not Present	No Investment	0
780	Retro-s		Present	Not	Present	Medium	2
795	Retro-s	present	Present	Not		Medium	2
797	Managed				Not Used	Not Used	0
804	Managed				Not Used	Not Used	0
820	Semi-nat				Not Used	Not Used	0
877	Managed				Not Used	Not Used	0
908	Semi-nat				Not Used	Not Used	0
911	Managed				Not Used	Not Used	0
917	Semi-nat				Not Used	Not Used	0
938	Managed				Successful	Successful	3
944	Semi-nat				Not in use	Not Used	0
945	Semi-nat				Successful	Successful	3
953	Retro-s	Present	Present	Present		High investment	3
977	Managed				Indeterminate	Nesting Attempt	1
987	Semi-nat				Successful	Successful	3
995	Retro-s	present	Not	Not		Low Investment	1
996	Managed				Not Used	Not Used	0
1018	Semi-nat				Successful	Successful	3
1023	Retro-s	No data	Present	Present	Present	High investment	3
1032	Managed				Not Used	Not Used	0
1045	Retro-s	No data	Not	Not	Not Present	No Investment	0
1049	Managed				Not Used	Not Used	0
1071	Managed				Not Present	Not Used	0
1080	Managed				Not Used	Not Used	0
1083	Managed				Successful	Successful	3

NEST_I	Category	2004–05	2005–06	2006–07	2007–08	Use Category	Ran
1093	Managed				Not Used	Not Used	0
1100	Retro-s	No data	Present	Present	Not Present	Medium	2
1191	Retro-s	present	Present	Present		High investment	3
1198	Semi-nat				Not in use	Not Used	0
1201	Semi-nat				Not in use	Not Used	0
1208	Managed				Not in use	Not Used	0
1211	Semi-nat				Not Used	Not Used	0
1230	Managed				Successful	Successful	3
1233	Managed				Failed	Failed	2
1234	Managed				Not Used	Not Used	0
1235	Managed				Not Used	Not Used	0
1258	Semi-nat				Not Used	Not Used	0
1261	Retro-s	present	Present	Not		Medium	2
1262	Managed				Not Used	Not Used	0
1268	Retro-s	present	Present	Not		Medium	2
1296	Retro-s	No data	Present	Not	Not Present	Low Investment	1
1299	Managed				Not Used	Not Used	0
1300	Retro-s	No data	Present	Present	Present	High investment	3
1304	Retro-s	present	Present	Not		Medium	2
1307	Managed				Successful	Successful	3
1320	Managed				Failed	Failed	2
1321	Semi-nat				Not Used	Not Used	0
1366	Managed				Failed	Failed	2
1367	Retro-s	Not	Not	Not		No Investment	0
1379	Managed				Not in use	Not Used	0
1381	managed				Not in use	Not Used	0
1382	Robyn				Successful	Successful	3
1384	Managed				Not Used	Not Used	0
1422	Semi-nat				Not Used	Not Used	0
1432	Managed				Not Used	Not Used	0
1446	Managed				Not Used	Not Used	0
1454	Managed				Not Used	Not Used	0
1471	Managed				Incubating/No	Nesting Attempt	1
1472	Managed				Not Used	Not Used	0
1481	Managed				Successful	Successful	3

NEST_I	Category	2004–05	2005–06	2006–07	2007–08	Use Category	Ran
1506	Managed				Not Used	Not Used	0
1523	Managed				Failed	Failed	2
1531	Semi-nat				Successful	Successful	3
1576	Managed				Failed	Failed	2
1581	Managed				Successful	Successful	3
1580	Semi-nat				Successful	Successful	3
1585	Managed				Not Present	Not Used	0
1611	Semi-nat				Successful	Successful	3

Appendix D
Nest site characteristics used to determine activity status during November

There are a variety of techniques used to estimate nest status, many of which were formed by expert opinion. This table was developed to show the combination of characteristics that may be present during the mid-late breeding season checks in November.

Table D.1 Nest site characteristics used by eagle specialists to determine activity status during the mid-late breeding season (November)

Survey Method	Green Leaves	Brown sticks	White-wash	Down	Prey remains	All grey sticks	6 wk old chick	Adult presence	Flat top	Egg
Productive/ground	Y	Y	Y	Y	Y	N	Y	Y	Y	N
Productive/helicopter	Y	Y	Y	Y	Y	N	Y	Y	Y	N
Productive/Fixed wing	Y	Y	Y	N	N	N	Y	Y	Y	N
Maintainted/ground	N	Y	Y	N	Y	N	N	Y/N	Y/N	N
Maintained/helicopter	Y/N	Y	Y	N	Y	N	N	Y/N	Y/N	N
Maintained/Fixed wing	Y/N	Y	N	N	N	N	N	Y/N	Y/N	N
Not used/ground	N	Y	Y	N	N	Y/N	N	N	N	N
Not used/helicopter	N	Y	N	N	N	Y/N	N	N	N	N
Not used/Fixed wing	N	Y/N	N	N	N	Y/N	N	N	N	N
Failed/ground	Y	Y	Y	Y/N	Y	Y/N	N	Y/N	Y/N	Y/N
Failed/helicopter	Y	Y	Y	Y/N	Y/N	Y/N	N	Y/N	Y/N	Y/N
Failed/Fixed wing	N	Y	Y/N	N	N	Y/N	N	Y/N	Y/N	Y/N

Y = present N = Not present

Appendix E
Habitat suitability model for the wedge-tailed eagle

Brown and Mooney (1997) studied the habitat characteristics of 60 nests in eastern Tasmania. All observed sites occurred on slopes between 0 and 35 degrees on south-easterly aspects and in forests greater than 27m in height.

A more recent analysis of current nest sites (2007) resulted in the parameters below. These were used in the development of the potential nesting habitat layer used in this study.

Table E.1 Suitable nesting habitat parameters adapted from Brown and Mooney (1997)

Slope	< 38o
Aspect	0 – 180o
P.I. (Photo interpretation data)	> Forest class E4
Analysis Height	Estimated from 30m of tree height

Appendix F
Proposed Expert System to increase efficiencies during decision making process while also providing more up to date nest locality and 'activity status' database for FPOs and researchers

Management Tools

Results obtained during the 2007–08 breeding season provide substantial information to aid develop of an expert based system to increase efficiencies during decision making processes while also providing a more up to date database and feedback system for FPOs. The various components considered would allow:

- database management
- reduction in the incidents of double nest checks which increases nest site disturbance
- removal of the likelihood of incorrectly assessing nests as inactive (false negatives)
- provision of a feedback loop for future dissemination of information
- a reporting system to provide annual productivity results
- development of database framework so new management methods/objectives can be quickly updated
- provision of an information hub for forest contractors so that up to date information and techniques are more easily accessed.

Structure of planning tool:

The planning tool would require the following features:

- Users can remotely access data i.e. login in password system with email contact to answer special questions.
- Forest planners are able to directly add nest reports, updating the system immediately and providing specialists with a way to double check data when received.
- The provision of a nest check booking system for the September and November periods to reduce incidents of double nest checks and inform other users who will be checking the nest (e.g. Person X ticks a box to inform the database he/she will check the nest. If another person, Y sees that someone else is checking the nest, they may also wish to order a report of the nest once the nest check is completed).
- Forest planners are provided with an up to date list of vantage points and access routes, including access issues and keys requirements. This reduces the need to contact a variety of people to get access while the database may also provide a formatted email to detail managers of activity planned (e.g. FPA would like to access to nest X on date x).
- A map which provides site co-ordinates, access issues, vantage points, dot point report of past season results and a list of details to be gathered during the visit in a report that can be taken into the field. This reduces time gathering maps and relevant information to conduct the nest search thereby greatly increasing efficiency.
- Forest planners are able to directly upload field data they have gathered to the system. Forest Planners (managers) will be sent a report detailing the results of the nest check. The framework of the system incorporates all specialist data and provides the result in the form of a report to managers while also updating the system. Such a system reduces the need to regularly consult eagle specialists since the recommendation are

based on details gathered by forest planners and specialists. This allows instant management results without the need to wait for specialists.

- The onus is on all managers to quickly submit activity data once collected.
- Reports can be provisioned by eagle specialists to inform them of the number of nests checked and by who. Nest audits by air will provide a method to evaluate the expert system to increase data accuracy.
- Such systems remove bias in interpreting results since the system uses real *Occupied*, *Not Used*, results derived from results of this study in order to determine true nest status.
- Expert systems free up specialists and advisory staff allowing them to deal with other important issues
- The eagle planning database would be incorporated into the current Threatened Fauna Advisor.

Some day-to-day eagle management issues, such as updating GPS accuracies or new nest co-ordinates, would be managed as part of the old system since inaccuracies can easily occur. These fields require maintaining current protocols using eagle specialists to maintain data quality.

Appendix G
Cost-benefit analysis of survey techniques

Work conducted during the 2007–008 season allowed a cost-benefit analyses to be conducted to evaluate cost of assessing productivity using various data collection techniques such as helicopter, fixed wing aircraft and ground nest surveys techniques (Table 1 and 2).

Ground Assessment

Ground surveys were by far the most informative technique that could be applied to investigate success as this method allows very detailed observations to be gathered. The accuracy of this technique is largely dependent on whether nests can be viewed from above. Where vantage points were not available, data accuracy dramatically reduced to the point where other methods had to be employed. The cost associated with this technique is high with dramatic increases where commuting large distances is required. This technique works best in circumstances where planners have unique knowledge of nest locations and vantage points. During the 2007–08 season specialists averaged visiting two nests/day. If planners had detailed knowledge for how to access nests, the number of sites able to be visited in a single day rose to five. Costs associated with ground surveys are detailed in Table 1.

Aerial surveys – helicopter

Due to the sometimes aggressive nature of breeding adults in defending nests the use of helicopters during and up until two months after the breeding season is not recommended; there have been collisions with helicopters near nests. While helicopters allow detailed observations to be gathered, they are by nature very noisy which causes significant disturbance to active nests. Techniques used to establish nest occupancy require aircraft to fly very slow and close to nests, as a result collisions with eagles are a major concern. The employment of helicopter surveys has been restricted to off season monitoring and should only be conducted with experienced personnel due to the dangers involved.

Fixed wing aircraft

Fixed wing aircraft survey methods have been used extensively to survey eagle nests in Tasmania. While fixed wings are considerably faster than helicopters, they are less accurate (Table G.2.). Fixed wing surveys should be conducted when chicks are approximately 4–6 weeks old, when they appear as large downy chicks on nest platforms. The number of nests able to be surveyed successfully during a four hour flight is approximately 25 nests using two experienced observers. The accuracy of this method is approximately 72%. This value is greater than that reported my Mooney (Mooney 1988) who estimated an average nest detection of 50% using a single observer. Due to the difficulty in locating nests from a fast moving aircraft, follow up ground surveys are sometimes required. With all aerial survey methods powerful aircraft should be used to allow rapid height gains to be achieved in tight gullies and if aggressive eagles are encountered. The cost benefit analysis provided below details the most suitable aircraft for survey operations.

Table G.1 Relative benefits of survey techniques for wedge-tailed eagles

	Cruising Speed when banked	Risk of collision	Appropriate survey period	Accuracy	Cost	Total for 2007/08 season	No. of nests surveyed	Estimated Survey Time (hrs)
Fixed wing	Fast	low	Year round	medium	$130/nest	$11,200.00	64	21
Helicopter	Slow	high	Sept and Feb	high	$268/nest	$5,900.00	22	3
Ground survey	Slow	NIL	Sept and Feb	Medium/high	$556/nest	$13,365.00	24	140.3

Table G. 2 Aircraft specifications and tolerances

	Cruise sp. kts	Stall sp. kts/RPM	Endurance hrs	Cost/hr	Climb Rate
Helicopter, Squirrel Eurocopter AS-350 B2 (single jet turbine)	110 kts	392 RPM, 3 blade	180 min + 30 % reserve	$1900	1500 ft/min (max)
Cessna 206 F	120 kts (216 km/hr)	50kts (90km/hr) @ 10% flaps	243 min + 30% reserve	$530	4000 ft/min (max)

Note: The cost benefit analysis includes wages, vehicle hire and hidden expenses. Fixed wing and ground survey estimates are based on the 2007–08 state-wide survey, while helicopter survey were confined to a small travel area with high nest densities.