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Using surveys of nest characteristics to assess the breeding activity of the Tasmanian Wedge-tailed Eagle

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A standardised protocol for surveying raptor breeding activity based on nest characteristics rather than observations of adults and chicks could reduce the cost and time required for surveys, increase sampling capacity and minimize disturbance to birds. We examined whether the breeding activity of the Tasmanian Wedge-tailed Eagle *Aquila audax fleayi* can be assessed indirectly by surveying nest characteristics in the late stages of breeding or after the breeding season. The presence or absence of nestlings (approximately 4–6 weeks old) in 75 nests was assessed either from the air or from the ground during the 2007–2008 breeding season. Two sources of data on nest characteristics were available and were considered separately. One set (37 nests) was collected after the breeding season by eagle biologists during aerial (helicopter) or ground-based surveys. The other set (38 nests) was collected during the breeding season, by trained forest planners during ground-based surveys. A high proportion of the nests containing nestlings that were surveyed by eagle biologists after the breeding season were in good condition, had flat tops, brown leaves, whitewash and prey remains. Nests without nestlings were more bleached than nests with nestlings. Classification tree analysis indicated that the presence of a flat top or whitewash were comparable models for data collected mid breeding season (26% misclassification). The presence of a flat top was the best predictor of the presence of nestlings for data collected after the breeding season (8% misclassification). Nest characteristics change during and after breeding activity, so survey timing is important to consider when determining the nest characteristics that best reflect breeding activity.

INTRODUCTION

Recent declines in many raptor populations around the world (Fraser *et al.* 1996; Mooney 2000; Soutullo *et al.* 2008) have been related to the negative effect of human activities, such as persecution, land clearance and timber harvesting (Bekessy *et al.* 2009). It is important to monitor raptors in order to detect population changes and threatening activities, and to facilitate appropriate management and conservation actions. Many techniques are available for monitoring raptors, and the most appropriate technique will vary with the species, location and objective of the program (Steenhof and Newton 2007).

Most widely-used monitoring techniques rely on assessments of breeding sites during the breeding season (Stjernberg *et al.* 2005; Steenhof and Newton 2007; Whitfield *et al.* 2007). Breeding activities are important to monitor, but raptors can be particularly sensitive to disturbance when breeding (Mooney and Taylor 1996). A monitoring program based on indirect signs of bird presence or breeding activity would minimize disturbance to breeding birds, because repeat surveys would not be required and surveys could potentially be conducted outside the breeding period. Indirect surveys that accurately reflect whether a nest produced a nestling could be used for population monitoring and for comparing the productivity of nests in areas subject to different disturbances and management activities. Some studies have used indirect evidence of activity at a nest to indicate nest use (Jackman *et al.* 2004; Katzner *et al.* 2006; Mooney and Taylor 1996; Whitfield *et al.* 2007), but to our knowledge no study has examined how reliable indirect signs are at predicting whether nests produce a nestling.

The Tasmanian Wedge-tailed Eagle *Aquila audax fleayi* is listed as endangered under state and federal legislation and is considered to be sensitive to disturbance during the breeding season (Mooney 1997). Eagle nests are located in reserves, and on land available for timber harvesting. Eagle management in production forestry areas involves pre-harvest surveys for nests, establishment of reserves around nests, and restrictions on nearby forestry activities during the core breeding season (Forest Practices Board 2002). During the breeding season (Fig. 1) Wedge-tailed Eagles construct or refurbish large nest platforms (~180 cm wide, Mooney and Holdsworth 1991) with sticks and leaves. Several nests belonging to one pair may be furbished in a given territory, but only one is used for breeding in any given year (Bell and Mooney 1999). Further details on the nesting habits of Wedge-tailed Eagles can be found in Mooney and Holdsworth (1991), Debus *et al.* (2007) and Bekessy *et al.* (2009).

The aim of the current study was to determine whether nest characteristics assessed during the later stages of the breeding season or after it reflect whether a Wedge-tailed Eagle nestling was produced.

METHODS

Data collection

Seventy-five Wedge-tailed Eagle nests were surveyed during the 2007–08 breeding season (Fig. 2). Thirty-seven of these nests were selected randomly from the Tasmanian Raptor Nest Database (Department of Primary Industries, Parks, Water and Environment 2007). The Raptor Nest Database contains records of all Wedge-tailed Eagle nest sites known in Tasmania, whether or not they have ever been used for breeding (1367 nests as of November 2011). Assessments of the remaining 38 nests were requested by forest planners for areas that would potentially be subject to harvesting.

The presence of nestlings in each nest was assessed from a fixed-wing aircraft (Cessna 206) during the second and third week of November when the nestlings were likely to be 4–6 weeks old. This is a third to half-way through the nestling period, and is earlier than the recommended acceptable age for assessing nest success (80%, Steenhof and Newton 2007). Nestlings were surveyed earlier than recommended because younger nestlings are large, white and downy and much more visible than older nestlings. It is possible that some mortality occurred later in the nestling period, but mortality is expected to be minimal in chicks over six weeks old (N. Mooney, pers. comm.). One nest could not be seen from the air so this nest was visited on foot and the presence or absence of a nestling was recorded. The timing of these surveys is indicated in Figure 1.

Listed in Table 1 are the nest characteristics (indirect signs) observed to vary between Wedge-tailed Eagle nests (Wiersma, pers. obs.) or identified in the literature as helping decisions on nest site occupancy (Jackman and Jenkins 2004; Steenhof and Newton 2007; Whitfield *et al.* 2007). Nests were surveyed for these characteristics either during the breeding season (mid-season data) or after the breeding season (post-season data). The post-season data were collected by eagle biologists in May/June, either by helicopter (16 nests) or from the ground (21 nests) (Figs. 1 and 2, Table 1). Observations made from the air and ground surveys were considered comparable because the observation distance and visibility of the nest platform were similar. The mid-season data (38 nests) were gathered from the ground in November by forest planners (Table 1, Figs. 1 and 2). These forest planners had been trained by eagle biologists to assess eagle nests, but data were incomplete for many nest characteristics. For some variables it was unclear as to whether or not the absence of data indicated that the variable had not been considered by the forest planner, or whether it was not detected at the nest. None of the observers assessing nest characteristics knew the results of the nestling surveys; that is, the study was double-blind.

Statistical analyses

Classification trees (De'Ath and Fabricius 2000) were used to identify the nest characteristics (Table 1) that best predicted the presence of a large downy nestling. Classification trees were used because they readily deal with missing data and they assess both categorical and continuous predictor variables and interactions between variables. Separate models were constructed for nest characteristic data collected mid- and post- breeding season. Maximal trees were constructed and cross-validation error was used to determine the optimal tree size used in the final models (De'Ath and Fabricius 2000). Alternate primary and surrogate splits were examined, and the final models were selected as those with the lowest misclassification rates of the trees composed of sensible ecological pathways. Classification trees were constructed using the 'mvpart' package (Therneau *et al.* 2007) in R (version 2.7.0).

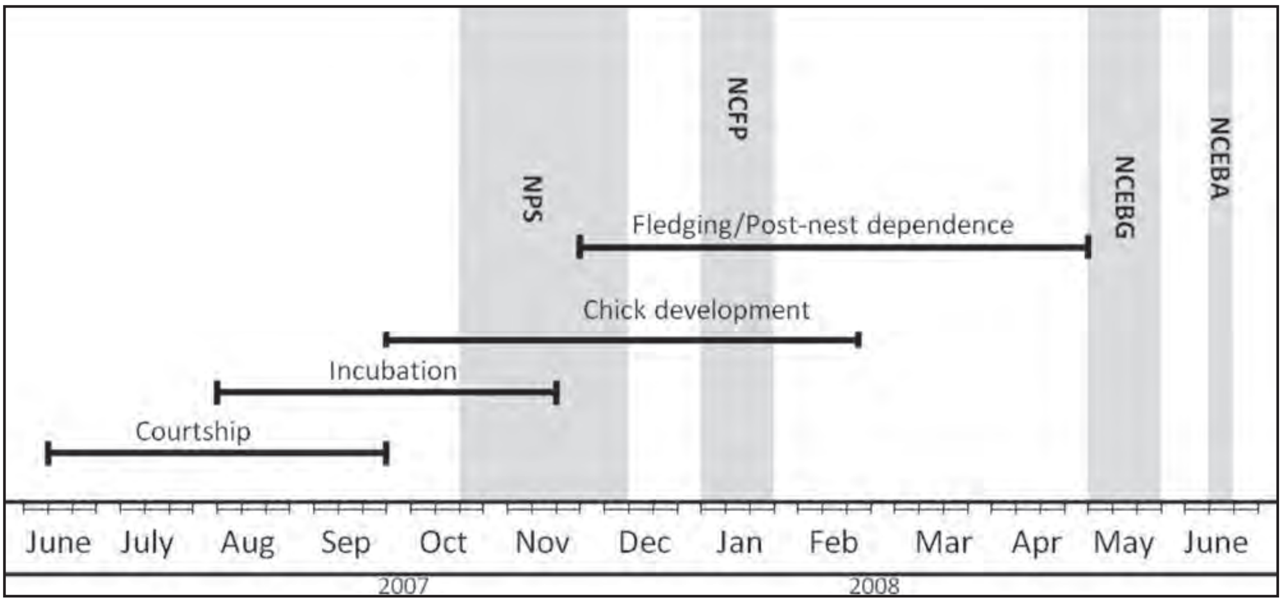

Figure 1. *Diagrammatic representation of the estimated timing of breeding activities for the Tasmanian Wedge-tailed Eagle nests surveyed in 2007–2008, indicating when the different surveys were done for the current study. The timing of breeding events is based on data from a concurrent study (Wiersma* et al. *2009). Timing of stages was extrapolated from estimated nestling age; courtship was assumed to take 42 days, incubation 45 days, nestling development 90 days and fledging and post-nest dependence 42 days (adapted from Bell and Mooney 1999, Olsen 2005 and Debus et al. 2007). NPS = Timing of surveys for nestling presence; NCFP = Timing of ground-based surveys of nest characteristic by forest planner; NCEBG = Timing of ground-based surveys of nest characteristic by eagle biologists; NCEBA = Timing of aerial surveys of nest characteristic by eagle biologists.*

TABLE 1

Nest characteristics and timing of surveys.

Nest characteristic	Timing of Observation	Details
Adult	MS,PS	Adult(s) seen at nest site or in close proximity.
Egg/egg shell	PS	Egg and/or egg fragments visible on the ground or in the nest.
Down	MS,PS	White fluffy down from chicks or adults observed on or around the nest.
Prey remains	MS,PS	Remains of prey (old carcass frames or freshly delivered items) visible at the nest. Flies and wasps often provided visual clues of items present.
Pellets	PS	Pellets (regurgitated roughage containing fur/feathers and bone) observed in the nest or on the ground below the nest.
Whitewash	MS,PS	White excrement splash marks visible in or below the nest (faecal matter)
Green leaves	MS,PS	Fresh green eucalypt leaves visible in the nest.
Brown leaves	MS,PS	Brown leaves visible in the nest, indicating that green leaves were present during the breeding season.
Fresh brown sticks	MS,PS	Recently added brown sticks (defined by lack of ultra-violet bleaching) visible in the nest.
Bleached sticks	PS	Degree of bleaching of nest structure. Bleaching occurs from sun damage when there is no fresh stick refurbishment. Where bleaching was present, nests were categorized as partially bleached or all bleached.
Nest decomposition	MS,PS	Presence of rotting woody debris visible at the base of the nest.
Leaching	PS	Green leaching visible at the base of the nest. Leaching is the result of phosphates deposited through excrement and bacteria leaching through the nest and onto the surrounding limbs below the nest structure.
Nest width	PS	The estimated width of the nest (cm) at the widest point.
Nest depth	PS	The estimated depth of the nest (cm) at the deepest point.
Flat top	PS	Visible compaction of the nest rim. This occurs when chicks walk on top of the nest during the late fledgling stage.
Degrading nest platform	PS	Nest structure is classified as intact or degrading according to the structural integrity of the nest and the supporting structure (e.g. branches).
Nest bowl	PS	A definite rim visible on the top side of the nest. This is generally more obvious in the earlier stages of the breeding period or at nests that are maintained but not used.
Nest condition	MS,PS	A subjective assessment of nest condition based on morphology. Poor: Nest loosely woven and collapsing; Average: Nest showing some signs of collapse but is largely intact and compact; Good: Structurally intact and compact.

PS – data collected after the breeding season (Fig. 1) by eagle biologists

MS – data collected during the breeding season (Fig.1) by forest planners

RESULTS

Eleven (30%) of the 37 nests that were randomly selected (i.e. post-season data) had a nestling and 26 did not. A higher proportion of the 38 mid-season nests had a nestling (55%). Details of the number of nests assessed for each nest characteristic is presented in Table 2. Many nest characteristics were common to both nests that had a nestling and those that did not. Nests that contained a nestling during the breeding season were generally found to be in good condition, were wide, had flat tops (as strictly defined in this study: Table 1, Fig. 3), visible brown leaves, whitewash and prey remains when surveyed after the breeding season (Table 2). Nests that did not have a nestling during the season were also frequently found to be wide with visible brown leaves after the breeding season. However, these nests were more bleached than the nests that contained a nestling (Table 2).

Nests surveyed mid-season had similar characteristics to those surveyed post-season despite the incomplete information collected. Nests containing nestlings generally had flat tops, visible fresh brown sticks and whitewash, but many of the nests without a nestling also had these characteristics (Table 2). Of the ten nests reported to have whitewash and green leaves, nine (90%) had a nestling. Of the 23 nests with visible whitewash and fresh brown sticks, 16 (70%) had a nestling. Of the ten nests that had both green leaves and fresh brown sticks, nine (90%) had a nestling.

The classification tree constructed using the post-season data had only one branch, the presence of a flat top (Fig. 3). The presence or absence of a flat top correctly predicted 91% of nests with a nestling and 92% of nests without a nestling (Table 3a). No alternative models were comparable in predictive ability.

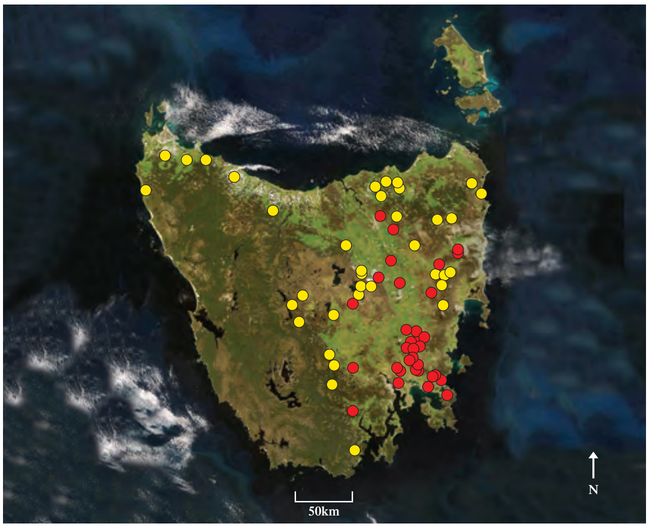

Figure 2. *Location of nest sites surveyed for presence of nestlings. Image courtesy of NASA's Earth Observatory.*

● *Nests surveyed post-season for nest characteristics (n = 37).*
● *Nests surveyed mid-season for nest characteristics (n = 38).*

The initial classification tree produced using the mid-season data found whitewash to be the best predictor of nests that had a nestling. Using this model, 95% of successful nests were predicted correctly. However, the model only correctly predicted 50% of nests without a nestling. Alternative models for the mid-season data were either the presence of green leaves, or the presence of a flat top. Analysis based on these variables was confounded by missing data (i.e. data not always collected by forest planners). We made the assumption that forest planners would have recorded green leaves or a flat top if these were visible and we reclassified all missing data for these two variables as 'absent'. Re-analysis of the modified mid-season data found the occurrence of a flat top had equal explanatory ability as whitewash. Using the flat top model, 62% of nests with a nestling and 88% of nests without a nestling were predicted correctly (Table 3b). Green leaves remained a comparable model with only slightly higher misclassification rates (31.6% misclassification if absence of data is assumed to mean green leaves were absent, compared to the 26.3% misclassification of the flat top and whitewash models).

DISCUSSION

This study explores whether assessing nest site characteristics during or after the breeding season can be used to determine if an eagle nest contained a nestling in the most recent breeding season. The results indicate that a small number of nest characteristics provide reliable evidence that a nest contained a nestling. The presence of a compressed flat top on the nest was identified as the best single predictor of the presence of a nestling. A flat top is generally produced when the nestling walks and jumps on top of the nest. A flat top provides some evidence that a nestling was produced, but does not indicate that the nestling actually fledged. The time taken for nestlings to compress nests so they have flat tops is not known. Data collected by forest planners during the breeding season had moderately high error (26%) for the model using flat tops as the predictor variable. However, it can be difficult to determine from the ground whether nests have flat tops, depending on the topography and forest structure at the nest site, so some of the nests classified as not having flat tops may not have been assessed for this attribute. Data collected after the breeding season by eagle biologists had a low error rate (8%), but two of the nests without nestlings (8%) had flat tops. Without the additions of fresh sticks to produce a nest bowl, nests will maintain the 'flat top' characteristic until they become weathered and slumped. Therefore the presence of flat tops on the misclassified nests may be the result of nestling presence in previous seasons.

The initial model constructed using mid-season data identified the occurrence of whitewash (faecal matter) as the best predictor of the presence of nestlings. However, while 91% of the nests with nestlings assessed after the breeding season had whitewash, so did 27% of the nests without nestlings. Whitewash can accumulate below a nest or underneath limbs whether a site is being used for roosting, as a display or feeding platform or as a breeding site (Jackman and Jenkins 2004; Olsen 2005; Steenhof and Newton 2007). This means that the presence of whitewash alone does not guarantee a nest contained a nestling.

The mid-season data indicated that the presence of green leaves might be an alternative predictor of nestling presence. Eagles line their nests with green leaves early in the breeding season and continue to line nests while they contain chicks (Bell and Mooney 1999; Olsen 1995; 2005; Jackman and Jenkins 2004; Wiersma *et al.* 2009). However, green leaves may be blown into the nest by strong winds (Wiersma, pers. obs.) and adults may line several nests in their territory (Mooney 1996), so the presence of green leaves during the breeding season also does not guarantee that a nest has been used for breeding. The green leaves used to line a nest eventually desiccate and turn brown, so the post-season model did not find green leaves to be an important predictor.

As nest characteristics can change over time, several features may be used together to help determine breeding activity. Nest platforms become bleached if no new material is added, so flat tops on bleached nests are most likely a result of breeding in the previous season. Flat tops to nests that are brown in colour are more likely to indicate more recent nestling presence in a nest. The presence of whitewash alone suggests recent eagle activity, but is not a definite indicator of breeding. The presence of whitewash in combination with green leaves and a flat top may be the best composite indicator that breeding activity is occurring. Although only a single indicator was identified in the statistically generated predictive models in the current study, a larger sample size would be likely to generate a composite indicator with greater accuracy for predicting nestling presence. The timing of the surveys will affect the particular combination of nest attributes that best reflect breeding activity.

Wedge-tailed eagle breeding pairs maintain several nests and not all nests within a territory were assessed during the current study. Therefore a record of a nest without a nestling does not mean that the breeding pair failed to produce a chick that season. Furthermore, as we only collected data on the production of nestlings but not clutch initiation, the nest characteristics

TABLE 2

The characteristics of nests in which a nestling was observed during the breeding season and those where no nestling was observed from surveys conducted during the breeding season by forest planners (MS) and after the breeding season by eagle biologists (PS)

Nest characteristic	% (and count) of nests with a nestling		% (and count) of nests without a nestling	
	PS	MS	PS	MS
Adult	9% (1 of 11)	10% (2 of 20)	4% (1 of 26)	25% (3 of 12)
Egg/egg shell[a]	9% (1 of 11)	–	0% (0 of 26)	–
Down[a]	9% (1 of 11)	100% (2 of 2)	0% (0 of 26)	0% (0 of 1)
Prey remains	55% (6 of 11)	18% (2 of 11)	8% (2 of 26)	8% (1 of 12)
Pellets	45% (5 of 11)	–	8% (2 of 26)	–
Whitewash	91% (10 of 11)	95% (19 of 20)	27% (7 of 26)	50% (8 of 16)
Green leaves	9% (1 of 11)	48% (10 of 21)	12% (3 of 26)	6% (1 of 17)
Brown leaves	73% (8 of 11)	14% (3 of 21)	50% (13 of 26)	12% (2 of 17)
Fresh brown sticks	18% (2 of 11)	94% (17 of 18)	23% (6 of 26)	73% (11 of 15)
Partially bleached sticks	0% (0 of 11)	–	35% (9 of 26)	–
All bleached sticks	0% (0 of 11)	–	27% (7 of 26)	–
Nest decomposition	45% (5 of 11)	–	27% (7 of 26)	–
Leaching[a]	0% (0 of 11)	–	4% (1 of 26)	–
Nest width	132 cm ± 51 SD (n = 11)	–	102 cm ± 37 SD (n = 24)	–
Nest depth	81 cm ± 42 SD (n = 11)	–	78 cm ± 58 SD (n = 24)	–
Flat top	91% (10 of 11)	57% (12 of 21)	8% (2 of 26)	12% (2 of 17)
Degrading nest platform	0% (0 of 11)	–	4% (1 of 26)	–
Nest bowl[a]	0% (0 of 3)	–	78% (14 of 18)	–
Nest condition				
Good	64% (7 of 11)	100% (18 of 18)	48% (12 of 25)	86% (12 of 14)
Average	36% (4 of 11)	0% (0 of 18)	16% (4 of 25)	14% (2 of 14)
Poor	0% (0 of 11)	0% (0 of 18)	36% (9 of 25)	0% (0 of 14)

– indicates this variable was not examined during the season by forest planners.

[a] indicates these variables were not included in the classification model for post-season data collected by eagle biologists due to lack of variability in the data.

identified in the current study do not indicate if breeding was initiated and failed at a particular nest site. Published rates of nest success are generally reported per territorial pair or per laying pair (Steenhof and Newton 2007) and so the rates at which nests produced nestlings in the current study should not be compared to rates of nest success published elsewhere. However, the current study does indicate that assessing nest characteristics during or after the breeding season could be used to establish a program to monitor changes in rates at which nestlings are produced at nests.

CONCLUSIONS

In production forests, as well as other areas, it is important to monitor and protect breeding raptors from disturbance. Although direct observation of breeding activity is the optimal monitoring and survey strategy (Steenhof and Newton 2007), such surveys can disturb the birds and for some species will require prohibitively expensive aerial surveys. We have shown that the presence of flat tops (as strictly defined herein), whitewash and green leaves is strong evidence that a nest contained a

Figure 3. *Photograph of nests classified as having (a) a nest bowl*
Photo: B.S. Plumpton and V.N. Thompson, Forestry Tasmania.

(b) a flat top
Photo: Chris Bond, Forestry Tasmania.

TABLE 3

A comparison of observed nestling presence in relation to predicted nestling presence (based on the presence or absence of a visible flat top), using (a) post-season data and (b) mid-season data.

a) Post-season Model

Observed	Predicted		Error
	Nests without a nestling	*Nests with a nestling*	
Nests without a nestling	24	2	7.7%
Nests with a nestling	1	10	9.1%
Error	4.0%	16.7%	8.1%

b) Mid-season model

Observed	Predicted		Error
	Nests without a nestling	*Nests with a nestling*	
Nests without a nestling	15	2	11.8%
Nests with a nestling	8	13	38.1%
Error	34.8%	13.3%	26.3%

nestling in the most recent breeding season. A single survey of these nest site characteristics may be a less expensive way to assess breeding activity at particular nest sites that minimizes disturbance to breeding birds. However, caution must be used when basing assessments on indirect signs. Topography and vegetation structure can make it extremely difficult to assess some attributes such as the presence of a flat top to the nest, so it is critical that data quality is monitored and maintained. The results presented here are for the Tasmanian Wedge-tailed Eagle, and the nest characteristics that best reflect breeding activity will vary with survey timing and species behaviour during the breeding season. However, our work has shown that surveying nest characteristics is a practical and accurate method for surveying eagle nests that will minimize disturbance to the birds.

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REFERENCES

Bekessy, S. A., Wintle, B. A., Gordon, A., Fox, J. C., Chisholm, R., Brown, B., Regan, T., Mooney, N., Read, S. M. and Burgman, M. A. (2009). Modelling human impacts on the Tasmanian wedge-tailed eagle (*Aquila audax fleayi*). *Biological Conservation* **142:** 2438–2448.

Bell, P. and Mooney, N. J. (1999). 'National recovery plan for the Wedge-tailed Eagle 1998–2003'. (Department of Primary Industries, Water and Environment: Hobart.)

De'Ath, G. and Fabricius, K. E. (2000). Classification and regression trees: A powerful yet simple technique for ecological data analysis. *Ecology* **81**: 3178–3192.

Debus, S. J. T., Hatfield, T. S., Ley, A. J. and Rose, A. B. (2007). Breeding biology and diet of the Wedge-tailed Eagle *Aquila audax* in the New England region of New South Wales. *Australian Field Ornithology* **24:** 93–120.

Department of Primary Industries, Parks, Water and Environment (2007). Raptor nest database. Hobart, Tasmania.

Forest Practices Authority (2007). 'State of the Forests Tasmania 2006'. (Forest Practices Authority: Hobart.)

Forest Practices Board (2000). 'Threatened fauna manual for production forests (revised version).' (Forest Practices Board: Hobart.)

Forest Practices Board (2002). 'Threatened fauna advisor'. (Forest Practices Board: Hobart.)

Fraser, J. D., Chancellor, S. K., Buehler, D. A. and Seegar, J. K. D. (1996). The decline, recovery and future of the Bald Eagle population in the Chesapeake Bay, U.S.A. In 'Eagle Studies' (Eds B. U. Meyburg and R. D. Chancellor). Pp. 181–187. (World Working Group on Birds of Prey: Germany.)

Gende, S. M., Willson, M. F., Marston, B. H., Jacobson, M. and Smith, W. P. (1998). Bald Eagle nesting density and success in relation to distance from clearcut logging in southeast Alaska. *Biological Conservation* **83:** 121–126.

Jackman, R. E. and Jenkins J. M. (2004). 'Protocol for evaluating Bald Eagle habitat and populations in California'. (Report by Pacific Gas and Electric Company for the U.S. Fish and Wildlife Service, Endangered Species Division: Sacramento, CA.)

Katzner, T. E., Bragin, E. A. and Milner-Gulland, E. J. (2006). Modelling populations of long-lived birds of prey for conservation: A study of Imperial Eagles (*Aquila heliaca*) in Kazakhstan. *Biological Conservation* **132:** 322–335.

Looman, S. J., Boyce, D. A., White, C. M., Shirley, D. L. and Mader, W. J. (1985). Use of ultralight aircraft for raptor nest surveys. *Wildlife Society Bulletin* **13:** 539–543.

McAllister, K. R., Owens, T. E., Leschner, L. and Cummins, E. (1986). Distribution and productivity of nesting Bald Eagles in Washington, 1981–1985. *The Murrelet* **67:** 45–50.

Mooney, N. J. (1996). Conservation of Wedge-tailed Eagles in Tasmania: the blunderbuss approach. In: *Australian Raptor Studies II: Birds Australia Monogragh 3* (eds G. Czechura and S. Debus). Birds Australia, Melbourne.

Mooney N. J. (1997) Conservation of wedge-tailed eagles in Tasmania: the blunderbuss approach. In 'Australian Raptor Studies II: Birds Australia Monogragh 3' (Eds G. Czechura and S. Debus). Pp. 99–107. (Birds Australia: Melbourne.)

Mooney, N. J. and Taylor, R. J. (1996). Value of nest site protection in ameliorating the effects of forestry operations on Wedge-tailed Eagles in Tasmania. In 'Raptors in human landscapes: adaptations to built and cultivated environments'. (Eds D. M. Bird, D. E. Varland and J. J. Negro). Pp. 275–282. (Academic Press: London).

Mooney, N. M. (2000). Appearances versus performance; managing endangered Tasmanian Wedge-tailed Eagles in forestry operations. In 'Practising forestry today. Proceedings 18th Biennial Conference of the Institute of Foresters of Australia' (Eds R. D. Chancellor and B. U. Meyburg). Pp. 321–331. (Institute of Foresters of Australia: Hobart).

Mooney, N. M. and Holdsworth, M. (1991). The effects of disturbance on nesting Wedge-tailed Eagles (*Aquila audax fleayi*) in Tasmania. *Tasforests* **3:** 15–31.

Olsen, P. D. (1995). 'Australian birds of prey: The biology and ecology of raptors'. (The Johns Hopkins University Press: NSW).

Olsen, P. D. (2005). 'Wedge-tailed Eagle'. (CSIRO Publishing: Melbourne).

Sanchez-Zapa, J. A. and Calvo, J. F. (1999). Raptor distribution in relation to landscape composition in semi-arid Mediterranean habitats. *Journal of Applied Ecology* **36:** 254–262.

Soutullo, A., Lopez-Lopez P. and Urios, V. (2008). Incorporating spatial structure and stochasticity in endangered Bonelli's Eagle's population models: Implications for conservation and management. *Biological Conservation* **141:** 1013–1020.

Stjernberg, T., Koivusaari, J., Hogmander, J., Ollila, T. and Ekblom, H. (2005). Population trends and breeding success of the White-tailed Sea Eagle *Haliaeetus albicilla* in Finland, 1970–2005. In 'Workshop Proceedings: Status of raptor populations in eastern Fennoscandia'. Pp. 151–159. (Russia).

Steenhof, K. and Newton, I. (2007). Assessing nestling success and productivity. In 'Raptor Research and Management Techniques'. (Eds D. M. Bird and K. L. Bildstein). Pp. 181 –191. (Hancock House: British Columbia, Canada).

Whitfield, D. P., Fielding, A. H., Gregory, M. J. P., Gordon, A. G., Mcleod, D. R. A. and Haworth, P. F. (2007). Complex effects of habitat loss on Golden Eagles *Aquila chrysaetos*. *Ibis* **149:** 26–36.

Wiersma, J., Koch, A., Livingston, D., Brown, B. T., Spencer, C., Mooney, N. and Munks, S. (2009). 'Eagle Nest Monitoring Project Year 1: 2007–2008. Establishing monitoring sites and investigating the relationship between nesting success of the Tasmanian Wedge-tailed Eagle and environmental variables'. Forest Practices Authority Scientific Report 8. (Forest Practices Authority: Hobart).