The Effects of Disturbance on Nesting Wedge-Tailed Eagles (*Aquila audax fleayi*) in Tasmania

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Abstract

*The wedge-tailed eagle (*Aquila audax fleayi*) is a subspecies endemic to Tasmania. Being a top-predator, it has valuable ecological roles and is naturally uncommon, a situation exacerbated by continued persecution. This eagle nests only in what is primarily oldgrowth native forest on sheltered aspects. Most nests are in closed* Eucalyptus *spp. forest and are located within the canopy layer. Territories may contain up to five alternate nests. In 1989, Tasmania had 138 eagle territories (95 of which were active) and 75 pairs producing young (usually one each), a level arguably sufficient to prevent inbreeding but which could result in loss of genetic variation. The species is an exceptionally shy nester and deserts easily if exposed to medium or high levels of disturbance such as intensive recreation, logging and roading. About two-thirds of territories are on private land and in State forest, areas with low breeding success. Essential requirements for protecting nests are inclusion in a copse of more than 10 ha and exclusion of heavy disturbance within 500 m during breeding. However, nests may be re-occupied and even those deserted should be conserved. We make suggestions for using already established procedures (e.g. in the Forest Practices Code) to better conserve nests.*

Introduction

In Tasmania, the wedge-tailed eagle (*Aquila audax fleayi*) is an endemic subspecies and one of the State's most widespread birds (Thomas 1979). It is a large, powerful eagle, typical of the genus and occupies a wide niche from top-predator to scavenger (Beckmann 1988; Meredith 1990). There is no evidence of interchange with mainland populations, the Tasmanian population probably being isolated for the 8 000 to 10 000 years since Bass Strait last formed. Such birds, physically specialised for thermal soaring, are very reluctant to cross more than about 10 km of open water. Where these species migrate, these limitations result in detours around large lakes and rivers.

Some ecological differences between Tasmanian and mainland Australian populations of *A. audax* are evident. High densities, where active nests can be as little as 700 m apart, are found in some semi-arid mainland areas that have extremely high abundance of the rabbit *Oryctolagus cuniculus* (e.g. Cupper and Cupper 1981). Also, many nests on the mainland are in isolated trees, occasionally even on cliffs (Crawford 1987). In Tasmania, closest active nests are about 6 km apart and all are in trees in native forest. There are no historic measures of the abundance of *A. a. fleayi* although anecdotal records suggest it was never common. Monitoring of population trends since 1978 using road-counts has suggested a stable population in Tasmania (N. Mooney, unpublished data).

Most large eagles use the same nest in consecutive years and are renowned as shy nesters (Brown 1976) although reactions of different pairs of a species to disturbance vary considerably (Scott 1985b). *A. a. fleayi* is no exception, the past few decades producing many local instances of nest desertion due to disturbance. With such long-lived birds, an obvious population decrease can be displaced in time from a point where breeding falls below replacement levels. Populations of large eagle species have dramatically decreased in many countries (e.g. Bijleveld 1974). Combinations of persecution, accidents, pollution, alteration of habitat and disturbance have usually been the cause (Allavena 1985; Phillips 1985) but individual factors such as human disturbance can have a large impact (Scott 1985a). However, because of their large home ranges, few opportunities of creating single reserves large enough to hold viable populations of such eagles exist (Thiollay 1989; Meyburg 1987). The inclusion of small numbers of territories in reserves may be a viable conservation approach if genetic exchange between reserves occurs. For small total populations, individual nests will need protection, regardless of land tenure.

We feared that expanding land development in Tasmania could threaten *A. a. fleayi* especially since other problems, principally persecution, exist. While investigating reports of nests, many disturbance situations were encountered, enabling a variety of *de facto* experiments. This allowed the progressive refinement of conservation guidelines in consultation with the forest industry and the development of monitoring techniques such as aerial survey. Detailed advice on protection of essential habitat for a number of Northern Hemisphere raptors is available (Call 1979; Anon. 1989) but there are important differences between the ecology of these species and *A. a. fleayi*. Preliminary advice for protecting eagle nests during forestry and land-clearing operations has been made (Mooney 1988a) and this paper presents refinement of that information concentrating on practical, realistic advice for protecting the species.

Methods

Locating nests

The whole of Tasmania (including islands) was considered for description of nest trees and nest sites (the physical situation within 200 m of the nest tree). Besides examining the literature and the Royal Australian Ornithologist's Union nest record scheme, from 1977 we actively solicited evidence of nesting from the Forestry Commission, the Department of Parks, Wildlife and Heritage and other government departments, private forest industry, private landowners and naturalists. Active searching was also used in particular study areas. In recent years, forestry guidelines have requested, if not required, the reporting of items of special interest, such as eagle nests, found during logging operations (Forestry Commission 1987; Taylor 1990).

Description of nest trees and sites

Nests were visited as we became aware of them and basic measurements taken of tree height, height to nest, height to first branch and diameter at 1.5 m above ground level. Because of the wide variety of means of finding nests and places involved, we believe the sample was representative of the population. Altitude at the base, aspect, slope, position on slope and proximity to water of the nest tree were recorded. The direction of prevailing winds in the incubation/early nestling period, September to November inclusive, was noted. Vegetation was described mainly on a structural basis (Specht *et al.* 1974). The availability of trees of comparable size to the nest tree in the site was recorded. Descriptions of fire frequency were made from land management records, annual ring counts of understorey species or node counts of honeysuckle (*Banksia marginata*). Areas of forest connected to the nest tree were described from measurement on the ground, maps and/or aerial photographs.

If a little-used nest was found, attempts were made to find alternate nests if the primary (most used) nest in that territory (that part of a home range containing nests and defended against conspecifics) was not already known. We preferred to visit nest sites outside the breeding season to minimise our impact but occasionally a visit in that period was undertaken because of consultation during a logging operation.

History of use

We made special attempts to follow the history of long-known nests, or nests with known disturbance. Our early attempts to age nests by their size proved unreliable. Security of position in a tree and exposure to winds seemed principally to govern nest size.

Disturbance

Within territories of a pair, the nest in use for breeding, the nest recently used (characteristically with droppings, fresh leaves, detritus and brown, overturned sticks as distinct from the bleached silver-grey of an unused nest) or, where there was no evidence of recent use, the nest in the best state of repair were categorised as to the prominent disturbance within 1 km and its minimum distance from the nest. Disturbance categories were:

- clearfelling/clearing;
- selective logging;
- roading/quarrying/building/heavy traffic;
- intensive farming - for example, cropping, dairying;
- non-intensive farming - for example, rangeland grazing;
- intensive recreation - regular boating or off-road vehicles, camping or group hunting/fishing, rock climbing;
- non-intensive recreation - walking, solitary hunting/fishing;
- directed disturbance - nest photography, nest-tree climbing; eagle(s) killed nearby; and
- negligible - none detectable.

Monitoring of productivity

Attempts to define productivity by climbing to inspect nests were abandoned early in the study because of severe disturbance effects and inefficiency. Contents of few nests could be seen by observation from the ground. Whenever possible, the contents of nests were checked in the late nestling period, mid-November to mid-December inclusive, by flying over the area in fixed-wing light aircraft (Mooney 1988b). When regularly used nests were found not to be in use, other nests in that territory were checked.

Productivity (number of fledglings) of a sample of the same 16 widely dispersed nests was monitored from 1983 to 1989 to access yearly variation. Mortality appeared to be very low in the second half of nestling life so we assumed chicks we counted that had at least some feathering could be regarded as fledglings.

Results

Population

Up to mid-July 1991 we knew the location of 133 nests representing 85 territories. Not all nests were known in all territories. From the behaviour of other adult eagles we knew the approximate location of a further 32 territories. For a given habitat, territories were distributed very regularly where nesting habitat was available. By using density data from areas we knew well, we estimated that a further 21 territories exist giving a total of about 138 territories for Tasmania. Although all territories were probably occupied by eagles, not all were used for breeding each year. Several previously productive territories were occupied by adult eagles but not successfully used for breeding for up to six years. In several territories, lone eagles persisted for two to three years before apparently finding a mate. Of the 57 territories closely examined in 1989, 40 (70.2%) were active, producing at least eggs and 30 (52.6%) fledgling young. On average, 1.07 chicks (maximum of two) were fledged per successful territory. Therefore, in any one year, Tasmania has about 95 active pairs representing 75 successful pairs, producing about 80 fledglings.

Productivity of the sample of 16 territories was consistent over the years 1984-89 with nine, seven, nine, eight, eight and eight young produced in each of those years. There tended to be some irregular rotation of success, that is, the same territories were not always successful.

Nests and nest trees

Of 94 nest trees described, 92 (97.9%) were in *Eucalyptus* species indigenous to Tasmania, one was in blackwood (*Acacia melanoxylon*) and one in King Billy pine (*Athrotaxis selaginoides*) (W. Jackson, pers. comm.). Five per cent of nest trees appeared dead.

On average, there were 1.5 nests (range 1-5) per territory we knew well. Alternate nests were usually within 200 m but sometimes when habitat was locally restricted they were over 1 km apart.

Heights of the 45 nest trees measured varied from 26 to 73 m, with diameters of 0.86-3 m, averaging 1.8 m. All had hollows and scars, and some had lost their crown, typical of large, oldgrowth eucalypts. The heights to nests were 54-80 per cent of tree height. The positioning of a nest within the canopy seemed very important. The canopy height range seemed to occur over a consistent proportion of the tree height regardless of absolute height. First branches occurred at 23-54 per cent of tree height. With rare exceptions, nest trees were the largest or equal largest (by height and girth) trees on the site. Where other similar trees were available, nest trees were those with greatest height to the first branch. Nest trees were all very robust and rarely seen to sway. Most nests were in emergent trees but in these cases they were built within the main forest canopy height range. Nests were up to 3 m^3 in volume and were usually located at the most robust fork, close to the trunk on the side away from the ground slope. All nests had some vegetative cover above them (even if dead), usually at least half the nest tree's crown. All but one had enough to give some midday shade to the nest.

Occasionally nests were located well above the canopy in emergents but in these cases the canopy had been modified by logging or clearing. None of these nests was active.

Nest-tree sites

All nests were on sloping ground from 4° to 32°, usually positioned between the lower and mid-slopes, always with the nest lower than the ridge ground level. On high slopes, nest trees were positioned relatively lower than on low slopes. Aspects of the nest sites varied widely. However, when slope aspects were related to direction of locally prevailing wind, eagles showed a clear preference for lee slopes. In territories where there were apparently suitably sized trees on windward slopes, there was obvious choice of sheltered positions. The highest recorded altitude of nest trees was 1100 m (Lake Ada) and the lowest 5 m (Arthur River).

Vegetation communities

There was great variation in species composition between nest-tree sites as could be expected from the wide distribution of territories. Most nest-tree sites involved multi-aged communities with more than 50 per cent of the trees as oldgrowth. Disregarding emergents, the canopy cover of successful nest sites was 30-90 per cent, the higher figure being rainforest canopy in mixed forest. No nests were in callidendrous rainforest. Over half the nest trees examined were in tall open forest above an open forest or closed forest understorey (definitions after Specht *et al*. 1974).

Table 1. Areas of oldgrowth forest attached to the primary nest tree in a territory, and breeding success of these nests in 1989. Numbers in brackets are expected numbers based on the standard provided by nests in forest copses > 100 ha.

Area (ha)	Nests	Successful	Failed	Not used
> 100	22	14	4	4
81 - 100	3	2 (1.83)	1 (0.5)	2 (0.67)
61 - 80	5	2 (0.3)	1 (0.84)	2 (1.4)
41 - 60	2	2 (1.2)	0 (0.33)	0 (0.44)
21 - 40	6	3 (3.0)	1 (0.84)	1 (1.1)
0 - 20	19	5 (11.6)	4 (3.2)	10 (4.2)
	57			
11 - 20	6	3 (3.7)	1 (1.0)	2 (1.3)
0 - 10	13	2 (7.9)	3 (2.2)	8 (2.9)
6 - 10	4	1 (2.5)	2 (0.7)	1 (0.7)
0 - 5	9	1 (5.5)	1 (1.5)	7 (2.0)

Copses associated with nest trees

There was an obvious decrease in nesting success when copse size fell to less than 10 ha (equivalent to a circle of diameter 356 m), becoming very low at less than 6 ha (Table 1). The shape of the copse did not seem to be important as long as it was 100 m or greater in total width at the nest tree.

Several nest trees were isolated from forest. Invariably they had been isolated during logging or clearing and we found no evidence that they had been used for breeding since isolation. Many nests were reported during logging or land clearing and left standing on or very near the edge of the remaining forest.

Nearly 40 per cent of nests were within 150 m of a significant watercourse and most nests were in gullies; only about 10 per cent were in situations that would be encompassed by streamside reserves as defined by the Forest Practices Code (Forestry Commission 1987; Taylor 1990).

Effects of disturbance

Rarely did eagles move from vision of a nest site even if severely disturbed such as when deliberately flushed by an observer. However, eagles were easily kept away past the survival point of the egg(s)/ chick(s). It was obvious that some human activities were more disturbing to eagles than others and some individual differences in reaction were apparent. However, a number of factors were evident, summarised below.

- Larger distances between nest tree and disturbance were less harmful. Critical minimum distances were 150 m for light disturbance, 250 m for medium and 500 m for heavy disturbance. There was some evidence that forest of greater height needed larger distances, possibly a function of observability from the nest.

- Out-of-sight disturbance was less harmful than in-sight disturbance at a given distance.

- Low rates of disturbance were less harmful. Flushing from the nest more than once every two days was harmful.

- Regular disturbance was less harmful than irregular, meaning predictability of disturbance through timing was less stressful for the eagles.

- Short periods of disturbance were less harmful. During incubation/brooding, 60 minutes appeared to be a critical period.

- Disturbance in extreme climatic conditions was more harmful through physical exposure of the egg(s)/chick(s). Chill factors can be very high in early spring and hyperthermia can occur in late spring - early summer.

- Directed disturbance, where the nest was the point or feature of the disturbing activity, was more harmful.

- Disturbance was less harmful later in breeding although peaks in sensitivity occurred during nest-lining, at laying, hatching and fledging both in terms of reaction of the eagles and the effects of their reactions; that is, older chicks were more robust. Unfortunately, in many areas, logging starts in August/September - right at the most sensitive time for nesting eagles (Fig. 1). Most desertions occurred in this period.

- Nests that had been successful the season prior to the disturbance were less likely to be deserted (nothing succeeds like success!).

- Disturbance from ground activities adjacent to the nest tree was less harmful when below the level of the nest. There seemed to be some relationship to slope angle. On steep slopes, disturbance above the nest should be kept further away or, better still, out of sight.

- Disturbance was cumulative. Frequent, light disturbance (for example, bushwalking) close to the nest could have deleterious effects similar to more distant, heavy disturbance (for example, road building).

On the basis of productivity, disturbances were categorised as low ($\geq$ 1 chick/territory), medium, or high ($\leq$ 0.33 chicks/territory) levels (Table 2). Of the 57 territories closely examined in 1989, five of the 19 (22.2%)

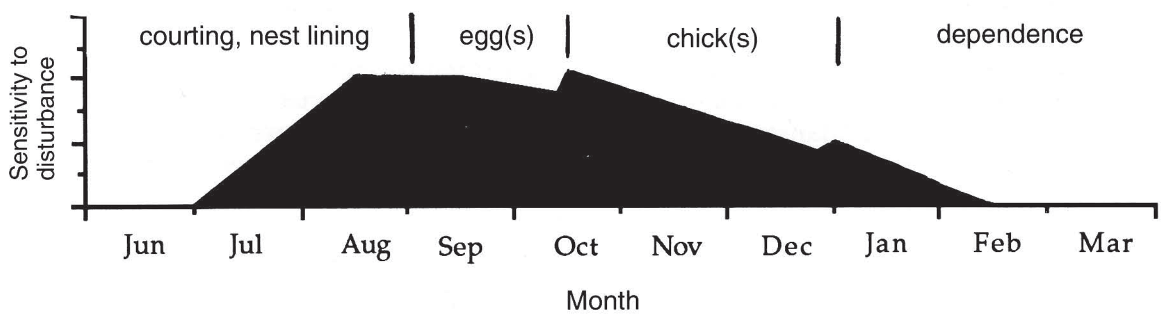

Figure 1. Sensitivity of breeding wedge-tailed eagles to disturbance. The shading represents the degree of sensitivity.

Table 2. Productivity and consequent nominated disturbance levels in 1989 (low - L, moderate - M, high - H). Numbers in brackets are those predicted based on negligible disturbance.

Disturbance level	Disturbance type	Productivity: Successful nests	Failed nests	Unused nests	Total	Fledgling/ Territory
Clearfell/clearing	H	3 (10)	4 (2.0)	7 (2.0)	14	0.17
Selective logging	M	2 (2.8)	1 (0.6)	1 (0.6)	4	0.5
Roading/quarrying	M	4 (5.6)	0 (1.2)	4 (1.2)	8	0.5
Intensive farming	M	2 (1.4)	0 (0.3)	0 (0.3)	2	0.67
Non-intensive farming	L	8 (7.1)	1 (1.4)	1 (1.4)	10	1.08
Intensive recreation	M	1 (2.8)	2 (0.6)	1 (0.6)	4	0.5
Non-intensive recreation	L	3 (2.1)	0 (0.4)	0 (0.4)	3	1.00
Directed disturbance	H	2 (3.6)	2 (0.7)	1 (0.7)	5	0.33
Negligible		5 (71.4%)	1 (14.3%)	1 (14.3%)	7	0.67
Total		30	11	16	57	

under heavy, eight of the 16 (50%) under medium, 11 of the 13 (84.6%) under light disturbance produced young, compared to five of the seven (71.4%) of those under negligible disturbance. This last, apparently incongruous result suggests that light disturbance has no more effect than negligible disturbance, that is, the birds can tolerate at least some disturbance.

Using the results from nests with negligible disturbance as a normal or ideal nesting result, we can predict what the other disturbance categories should produce if disturbance had no effect. If logging, roading, heavy traffic or quarrying occurred within 500 m of a nest tree in the breeding season, desertion for that season was almost certain. Roading also created access with repercussions of disturbance, even persecution.

Although the sample was small, there was some evidence that higher intensity of recreation resulted in lower productivity. Selective logging, although similarly disturbing to clearfelling during the operation, destroyed less habitat. If the core 10 ha was not logged and nearby thinning restricted to less than 50 per cent of trees while retaining canopy height, the medium- to long-term prospects for breeding were good. Any change of habitat in the core 10 ha decreased this probability.

Directed disturbance could be very disruptive to nesting. For instance, several desertions were caused by over-zealous photographers. We caused several temporary desertions in our early attempts to climb nest trees. Similarly, a nest near the Arthur River used regularly for breeding since the late 1930s (D. Johnston, pers. comm.) has been deserted since 1982, coincidental with greatly increased recreational boating.

Fire itself was rarely a disturbing factor other than in extremes, that is, killing/destroying nest trees. This was uncommon and occurred only with vigorous fires on steep slopes, as with the nest at The Patriachs, Flinders Island (D. Smith, pers. comm.), or very hot fires such as regeneration burns, for example, Sumac Road, north-western Tasmania, where a nest tree in a small copse left in a logged area was burned (Photo 1). We suspect that the choice of trees with high first branches is an adaptation for minimising fire risks to the crown and nest. Probably this also adds some protection from climbing predators.

Certainly we found nest trees exceptionally hard to climb.

There seemed to be no obvious relationship between numbers of nests per territory and type of disturbance. However, high numbers of nests seemed to occur where eagles had many choices of sites and there was regular disturbance meaning there was incentive to move and the birds could move. Territories where habitat loss and disturbance were severe often could only physically contain one nest, others being lost and not recorded.

We know of five cases of re-occupation of nests that were heavily disturbed by logging. Two involved selective logging. Breeding re-occurred after several decades, apparently when the remaining trees matured sufficiently to give the required shelter. Three cases involved clearfelling from the lee and downhill side almost to the nest tree and the nests were re-occupied three, five and six years later. The latter two cases involved use of alternate nests for that period, then a return to the original nest. Re-occupation after desertion caused by light or medium disturbance was more rapid, usually within two seasons.

In many cases, adult eagles occupied territories but were not breeding successfully or were breeding irregularly (for example, one year in six). In all cases where breeding did not occur for more than two consecutive seasons, high disturbance levels existed. Removal of resident eagles (for example, by shooting) occasionally had effects beyond the loss of that number of eagles to the population. Often their territories were not used for breeding for two to three years afterwards.

Tenure and security of reservation

The vast majority of nests surveyed were on private land or in State forest (Table 3).

Considerable efforts were made to find nests outside these tenures, for example, in National Parks, so as not to bias the sample through the many nests found during land development. The few nests on land with high security of reservation performed well (83% breeding, n=6) compared to those with medium (48.2% breeding, n=27) and poor security (45.5% breeding, n=22). This suggests that territories on land with anything but high security of reservation are at risk.

Discussion

The key habitat of nesting *A. a. fleayi* was shown to be at least 10 ha of little-disturbed forest, consisting primarily of oldgrowth eucalypt on sheltered aspects. Although a 10 ha area may maintain the nesting efforts of a pair of eagles, such small areas are very prone to degradation by edge effects, particularly fire (Photo 1, for example, Loyn 1987). We believe an additional, surrounding 10 ha is necessary to protect the core 10 ha if it is isolated.

Photo 1. Small copse surrounding a nest tree isolated by logging and killed by a regeneration burn.

Table 3. Land tenure, security of reservation and breeding success of eagles in 1989 (= high security; o = medium and x = low).*

Tenure	Number of successful nests/(%)	Number of nests surveyed/(%)	State total/(%)
x Private	9 (39.1)	23 (40.3)	46 (33.3)
o State Forest	9 (45)	20 (35.1)	50 (36.2)
* Forest Reserve	1 na	1 (1.8)	4 (2.9)
o Crown Land	3 (75)	4 (7.0)	9 (6.5)
o Protected Areas	1 na	2 (3.5)	4 (2.9)
* Nature/Muttonbird Reserve	1 na	1 (1.8)	3 (2.2)
o Conservation Area	1 na	1 (1.8)	5 (7.3)
* State Reserve/National Park	3 (75)	4 (7.0)	13 (9.4)
o Hydro-Electric Commission	0 na	1 (1.8)	2 (1.4)
* Quarantine/Military	0 na	0 (0)	2 (1.4)
	28	57	138

Positioning of protective areas should take slope into account. On flat land, the forest can be more or less equally distributed around a nest, with some concentration to windward. On steep slopes (already in the lee), protective forest should be concentrated upslope (Fig. 2). Inside the 10 ha area needed as a minimum reliable conservation measure, disturbance should be minimal. Ideally, activities that are highly disturbing should be positioned outside this area so as to be out of sight of the nest and/or timed away from the breeding season (August - January inclusive). Within the breeding season, disturbance should be timed as late as possible. Similar definitions of primary and secondary protective zones have been made for forest nesting bald eagles (*Haliaeetus leucocphalus*) and golden eagles (*Aquila chrysoetas*) (Call 1979).

Although these measures can be required under forestry regulations, often the clearing of private land will involve voluntary conservation efforts. Where financial constraints force the landowner to consider less than 20 ha, we recommend conservative, selective logging. The canopy height must be maintained and this logging done outside the breeding season.

Accepting that the nest originally used in a territory undisturbed or little disturbed by people can be assumed to be the best (i.e. most productive/successful) all nests are important. Besides their obvious use for breeding, nests are often used for feeding and roosting and act as territorial flags. They are an obvious centre of social activity in a territory.

Loss of actual nest trees has obvious negative connotations for the eagles but the short- to medium-term loss of critical areas of associated forest is equally serious. The greatest advantage of leaving any nest tree was that they were in sites chosen by the eagles.

Regrowth can produce forest that will allow nesting in the more distant future. Where all known nests in a territory are destroyed, at least three suitable 'best choice' areas of oldgrowth forest should be left within 2 km of the *loci* of the original nests. In the worst-case scenario, areas of regrowth, preferably associated with habitat trees or other oldgrowth, should be assigned the future role of providing eagle nest habitat.

Desertion of nests by *A. audax* can benefit other species. On mainland Australia, the Australian magpie (*Gymnorhina tibicen*) and the peregrine falcon (*Falco peregrinus*) regularly use old eagle nests (Cupper and