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NEST-SITE SELECTION, DIET AND PARENTAL CARE OF THE WEDGE-TAILED EAGLE *Aquila audax* IN WESTERN NEW SOUTH WALES

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Nest-site characteristics and selection of the Wedge-tailed Eagle *Aquila audax* were studied in 1997 at Fowlers Gap, in arid western New South Wales, Australia, by measuring parameters of nest trees (n = 9 active, 31 inactive) and other trees (n = 150 in circular plots around nest trees). Parental behaviour and prey items at two nests were recorded by remote time-lapse video surveillance, from week 4 of the nestling period to fledging. Active nests were mostly in live gums *Eucalyptus* sp. in creeks, whereas most inactive nests were in non-eucalypts or dead trees on ridges. Riparian nest trees were significantly taller, with larger crowns, than nest trees on downs or ridges, and non-nest trees in creeks; ridge nest trees were significantly taller than ridge non-nest trees. Six clutches were all of two eggs; fledging success was 0.6 young per attempt (n = 9). The eagles' breeding diet consisted of mammals (44% by number), birds (6%) and reptiles (34%): mostly rabbits *Oryctolagus cuniculus* (33%), juvenile kangaroos *Macropus* sp. (6%) and Bearded Dragons *Pogona vitticeps* (29%). By biomass, important prey were mammals (77%: rabbits 45%, kangaroos 26%) and reptiles (12%). Parental behaviour is described, and the video surveillance method is evaluated.

INTRODUCTION

There have been many studies on the ecology of the Wedge-tailed Eagle *Aquila audax*, quantifying aspects of diet and prey selection, nest-site selection and dispersion, and breeding biology (see Marchant and Higgins 1993 for a review; also Olsen and Marples 1992; Burnett *et al.* 1996; Sharp 1997; Richards and Short 1998; Debus and Rose 1999; Falkenberg *et al.* 2000; Harder 2000; Aumann 2001a,b; Sharp *et al.* 2001, 2002a,b; Olsen *et al.* 2006). Some of these studies, and others in progress (Davey and Pech 2004; Fuentes *et al.* 2004), have examined the effect of food supply or nest sites on eagle breeding success. However, other than the study of Harder (2000) there has been little quantification of breeding behaviour and parental care in the Wedge-tailed Eagle in the field. Anecdotal information is mainly from captive birds (reviewed by Marchant and Higgins 1993; see also Fleay-Thomson 2002), photographic studies (Cupper and Cupper 1981; Hollands 1984), and an observational study of one breeding event (Allott *et al.* 2006).

Following the impact of the calicivirus (haemorrhagic disease) on the population of the European Rabbit *Oryctolagus cuniculus* in the Australian arid zone, there may be effects on the Wedge-tailed Eagle's prey composition, population or breeding success (Falkenberg *et al.* 2000; Sharp *et al.* 2002a; Davey and Pech 2004). The virus arrived in the present study region in spring 1996 (Sharp *et al.* 2002a). Dietary studies have investigated the role of the rabbit in the eagle's ecology, but such studies usually rely on the analysis of prey remains and regurgitated pellets, which may have inherent biases (Sharp *et al.* 2002b). Attempts to overcome these biases can include direct observation of prey items delivered to nests, but this method is labour-intensive and sample sizes are limited by logistics. The number of nests that can be watched simultaneously is limited (without introducing multiple-observer bias in aspects such as prey size or identity), and long periods of observation are not practical.

This study sought to investigate aspects of the nesting biology of the Wedge-tailed Eagle (nest-site characteristics and selection, diet, potential prey populations, and parental roles during the nestling period), with behaviour and prey recorded using remote surveillance of nests by time-lapse video. The aims of the study were to identify characteristics of nest trees compared with non-nest trees; quantify prey items in relation to the availability of certain species; describe and quantify parental behaviour in relation to brood size and chick growth; and evaluate the video-surveillance method for observing raptors. Data on nest spacing and dispersion from the present study (Silva 1998) were incorporated into the discussion by Sharp *et al.* (2001).

STUDY AREA AND METHODS

Study site

The study was conducted at Fowlers Gap Arid Zone Research Station (31°05'S, 141°45'E), 112 kilometres north of Broken Hill in far western New South Wales. The station covers 39 200 hectares in a semi-arid to arid landscape used for grazing of livestock. Most of the area is high sandstone ranges with belts of Mulga *Acacia aneura*, she-oaks *Casuarina* and chenopod shrubs, grading to minor ridges and plains covered in perennial grasses. Watercourses are lined with River Red Gum *Eucalyptus camaldulensis.*

Nests

In 1997, Wedge-tailed Eagle nests were located during habitat searches by walking or driving (vehicle or trailbike traverses), initially in March then again between mid-July and late August (incubation and nestling periods) to determine eagle activity. Nests were easily identified by their size relative to other raptor nests. Each nest was recorded by GPS and plotted on a topographic map, classified as active (adult, eggs or chicks on/in nest) or inactive (no sign of activity, or activity did not proceed beyond the presence of fresh nest material), and categorised according to topographic position: 'ridge' (narrow elevated surface generally >200 m elevation), 'creek' (<20 m from a major tributary or creek bed), or 'downs' (>20 m from a major tributary or creek bed and located on flat to undulating terrain, i.e. 'rolling downs').

Nest height was measured from the ground to the top of the nest (as nest depth varied), using a clinometer and trigonometry. Nest width and depth were measured or, for trees that could not be climbed, estimated. Nest position was measured as percentage of tree height (0% = lowest position, at the base of the tree; 100% = highest position, at the top of the tree). Nest-site characteristics were measured in circular plots surrounding each nest. For 'ridge' and 'downs' nests, the nearest tree (live or dead, >2.5 m tall) in each 90-degree sector of the circle was measured, and for 'creek' nests, the nearest two trees (>6 m tall) on each side of the creek were measured. Tree height and crown depth were measured using a clinometer, 'crown' defined as being from the lowest live branch to upper live branches, and the depth of green crown was calculated as a percentage of tree height. Crown sectional area was measured by plumbing the edges of the crown to the ground, using the base of the tree as the centre point to form several triangles whose area was calculated using Heron's Law (see Silva 1998 for details). Tree condition (foliage cover) was categorised as sparse (<5% of the tree covered in foliage), sparse–medium (5–25% cover), medium–dense (25–75% cover), or dense (>75% cover). Tree density immediately around each eagle nest was calculated by a modified point-quarter method (Cottam and Curtis 1956), using the mean distance from the nest to the four nearest trees in the plot. Tree height, crown depth and crown sectional area of these four nearest-neighbour trees were compared with those of nest trees within habitats. Only live trees were used in comparisons of crown attributes, as nests in wholly dead trees may have been built when the tree was alive (or partly so) and abandoned when the tree died.

Statistical analysis

All nests, active and inactive, were used in calculations of mean nest-site parameters. Statistical comparisons of nest and non-nest trees were undertaken using SPSS for Windows V7.0. Between-habitat comparisons of nest trees were made using one-way ANOVA, with variances tested for homogeneity using Levene's test. Kruskal-Wallis and Mann-Whitney U non-parametric tests were used to compare ordinal independent variables between and within habitats, respectively. Matched samples of nest and non-nest trees were compared within habitats using the Wilcoxon signed ranks test. A significance level of 5 percent was used for all statistical analyses. Data are given as mean ± standard deviation.

Behaviour and prey

Observations on diet and parental care were recorded by a time-lapse camera powered by a photo-voltaic system (see Margalida *et al.* 2006 for a review and prior references on the method). The camera was a monochrome CCD video module with a 3.6 millimetre wide-angle lens and 380-line resolution (Oatley Electronics, Sydney). The camera was cased in a waterproof housing (5 x 5 cm) and mounted on a branch of the nest tree, on the north side (back to sun), so the field of view encompassed the whole nest. The unit was linked to a video recorder (Panasonic AG 6040) approximately 10 metres from the base of the tree, and powered by solar panels linked to lead-acid batteries (see Silva 1998 for details).

The video systems were initially set up at three active nests in early July during the incubation period, but after breeding failure at all three (one nest abandoned, two clutches failed to hatch) the systems were moved to three other active nests: one camera installed from early August during incubation, two from late August when (a) an egg was pipping (but subsequently failed), and (b) when a small chick (approximately 3 weeks old) was being brooded. The video system recorded at one frame per second onto a three-hour cassette, with the unit programmed to record for 120 hours, starting each day at first light (0515–0600 h) and finishing at last light (1800–1845 h).

Recording at the first successful nest (Nest 1) started on 16 September, approximately three weeks after the hatching date (23 August), and ceased when the first of two fledglings left the nest at just over 10 weeks old (620 h of video over 49 days). The single chick at the second nest (Nest 2) was recorded from 2 September (when 3–4 weeks old) to 20 October when it left the nest, for nearby branches, for the first time (602 h of video over 49 days). Behavioural categories in this study were as described by Brooker (1974) for the Wedge-tailed Eagle, and Ellis (1979) for the Golden Eagle *Aquila chrysaetos*. The video system provided instantaneous scans ('snapshots') at one-second intervals throughout the day, as the basis for scoring and quantifying each behaviour type (as frequency or duration) during subsequent analysis of videotapes. Only one observer (Silva) viewed and analysed the video footage.

Prey brought to the two nestling broods was recorded by the video systems at the nests. Individual prey items were identified, then categorised as mammal, bird, reptile or indeterminate (if obscured or too small to recognise). The time, date and prey brought by each parent were recorded, to give prey-delivery rate and the frequency of each prey class over time for each nest.

Prey populations

Populations of potential prey animals were surveyed. The densities of total animals, females and young at foot of the Western Grey Kangaroo *Macropus fuliginosus*, Eastern Grey Kangaroo *M. giganteus*, Euro *M. robustus* and Red Kangaroo *M. rufus* in four paddocks on the station were calculated by a fixed line-transect method (Buckland *et al.* 1993) sampling 21.8 square kilometres in January, March, July and October 1997 (Witte and Croft, unpublished data). Numbers of lambs were obtained using station records of lambs marked at the end of August 1997, to calculate lamb density in lambing paddocks.

RESULTS

Eagle population and breeding

Nine active nests were located on the station: seven in the 'creek' habitat, one in the 'downs' habitat and one in the 'ridge' habitat. An additional 31 inactive nests were found, many of them clustered around active nests and thus probably the alternative or disused nests of those pairs. These data do not equate with the total number of occupied territories, as a few of the more isolated inactive nests may have been the nests of pairs that did not attempt to breed in 1997.

In 1997, six clutches were all of two eggs; nine breeding attempts resulted in three successful outcomes (one brood of one, two broods of two, including the two study nests), giving 0.6 young per attempt. However, at least some of the failures were probably researcher-induced. Therefore, these figures may not be representative of 'normal' breeding success at Fowlers Gap. In two cases, after initial installation of the video system the subsequently deserted clutches (of two eggs) were judged to be infertile (L. Cupper pers. comm.). In another case, the camera was installed when one egg (of a clutch of two) was pipping, but the nest was then abandoned before hatching. In the final cases, the clutches (both of two eggs) were abandoned (a) after installation of the video camera, and (b) after a colleague set up equipment for filming; in the latter case the adults were notably shy. In one other failure, a brood of two small chicks had disappeared from the nest within 10 days of a tower being set up by a colleague (after they had hatched) for later filming.

Nest-site characteristics

All 'creek' nests were situated in live River Red Gums. Nests in the 'downs' habitat were situated in Red Gums (n = 2), Mulgas (2), *Eucalyptus* sp. (1), she-oak *Casuarina* sp. (1) and dead trees (2). 'Ridge' nests were situated in Mulgas (11), Belah *Casuarina cristata* (1) and dead trees (6). Active nests were found only in live trees: Red Gums (7, all 'creek'), eucalypt (1, 'downs') and Mulga (1, 'ridge'). Nest size averaged 118 ± 31 centimetres wide x 83 ± 41 centimetres deep (n = 40), with no significant difference across habitats (width: $F_{3,27}$ = 2.124, P >0.05; depth: $F_{3,27}$ = 1.415, P >0.05). The nine active (i.e. newly built-up) nests were 110–190 centimetres wide x 60–180 centimetres deep (mean 133 ± 26 cm wide x 103 ± 32 cm deep), so some of the smaller inactive nests may have been old wrecks.

Mean nest height, crown depth and tree height for 'creek' nests were significantly greater than for 'downs' and 'ridge' nests (Dunnett T3 test; P <0.05). All nests averaged in the top half of the tree in all habitats, but nest position was significantly lower in 'ridge' nest trees than in 'creek' nest trees (Dunnet T3 test; P <0.05). Crown depth of nest trees averaged greater than 60 percent of tree height across all habitats, but differed between habitats (Kruskal-Wallis test; P <0.01). Local tree density around nests was similar across habitats, though with high variance (Table 1).

'Creek' nest trees were taller (P = 0.001) and had a greater crown depth (P = 0.001) than neighbouring non-nest trees, and the crown sectional area of nest trees was also greater than that of neighbouring non-nest trees (P = 0.01) (Wilcoxon signed ranks test). 'Ridge' nest trees were also taller than neighbouring non-nest trees (P <0.01). Otherwise, parameters for 'ridge' and 'downs' nests did not differ for nest trees versus neighbouring non-nest trees within those habitats (P >0.05). There were no significant differences in proportional crown depth (i.e. crown depth/tree height) between nest trees and non-nest trees within any habitat (Tables 1 and 2).

Foliage condition (% cover) of live nest trees was similar across habitats (Table 1; $\chi^2_2 = 5.87$; P >0.05), and between nests that were active and inactive (Table 3; $\chi^2_1 = 0.789$; P >0.05). The average crown condition of eucalypts, acacias and casuarinas was medium-dense (i.e. 25–75% foliage cover). When compared separately for each tree species, foliage condition was similar for nest trees and non-nest trees regardless of habitat type. Active nests averaged higher, in taller trees with deeper and wider crowns, than inactive nests (Table 3), but this tendency was influenced by the fact that most active nests were in Red Gums in 'creek', whereas most (23 of 30) inactive nests were on 'downs' (6) or 'ridge' (17) and mostly in Mulgas.

TABLE 1

Parameters of nest trees for 'creek', 'downs' and 'ridge' Wedge-tailed Eagle nests at Fowlers Gap: mean ± standard deviation. Numbers in parentheses for each category = sample size; in data field = range. Nest position refers to percentile band in tree (0 = ground level, 100 = top); crown cover = proportion of tree covered in foliage; crown area = sectional area projected on ground; local tree density was determined within circular plots around nests; tree foliage condition rated as sparse (1) to dense (4) (see Methods text).

Parameter	Creek (14)	Downs (7)	Ridge (18)
Nest height (m)	10.4 ± 2.4 (7.3–15.3)	6.2 ± 1.9 (2.8–8.5)	3.3 ± 1.4 (1.5–7.3)
Nest position (%)	67.7 ± 12.8 (44.0–92.4)	70.4 ± 8.4 (36.7–83.3)	55.0 ± 16.5 (35.0–100)
Tree height (m)	15.4 ± 2.0 (13.0–19.8)	8.9 ± 3.0 (5.8–13.5)	5.9 ± 1.2 (4.3–7.8)
Crown depth (m)	13.1 ± 2.7 (8.3–19.0)	4.0 ± 3.6[a] (0.8–7.5)	2.9 ± 2.6[b] (0.3–6.0)
Crown cover (%)	84.5 ± 8.5 (60.0–96.2)	61.3 ± 34.0[a] (11.1–83.3)	68.0 ± 23.1[b] (6.3–85.2)
Crown area	156.8 ± 81.4 (79.4–265.5)	43.3 ± 50.6[a] (3.4–125.3)	11.7 ± 12.6[b] (0.5–40.6)
Tree density (n/ha)	1174.1 ± 1123.5 (64.8–2332.9)	154.2 ± 17.0 (142.8–219.5)	235.8 ± 24.0 (186.5–268.3)
Tree condition	3.4	2.9	2.4

[a]Mean of six live trees, as one dead

[b]Mean of 12 live trees, as six dead

TABLE 2

Parameters of non-nest trees in 'creek', 'downs' and 'ridge' habitats at Fowlers Gap: mean ± standard deviation for four nearest-neighbour trees (live and dead) around each of the nests in Table 1. Parameters and conventions as in Table 1.

Parameter	Creek (54)	Downs (28)	Ridge (68)
Tree height (m)	10.5 ± 3.8 (5.8–18.0)	7.1 ± 2.4 (3.5–13.0)	4.7 ± 1.3 (2.8–8.0)
Crown depth (m)	8.6 ± 3.2 (0–14.8)	4.6 ± 3.0 (0–10.5)	2.3 ± 2.2 (0–6.5)
Crown cover (%)	79.8 ± 22.0 (0–100)	62.8 ± 35.2 (0–100)	41.4 ± 34.6 (0–95.8)
Crown area	91.1 ± 64.0 (0–297.0)	18.0 ± 17.1 (0–69.1)	9.4 ± 12.7 (0–68.4)
Tree condition	3.1	2.4	2.3

Potential prey populations

The total macropod population was highest in July, as was that of adult females. However, the density of young at foot remained stable at about 3–3.5 animals per square kilometre through the year (Witte and Croft, unpubl. data). There were 3 099 lambs marked on Fowlers Gap in August 1997, giving a density of 11.7 live lambs per square kilometre in lambing paddocks.

Diet

The eagles delivered mammals (44% by number), birds (6%) and reptiles (34%) to the nest, with 16 percent of items unidentified (in some cases indeterminate pieces of vertebrate carcasses; n = 192 items: Table 4). Avian items, and some mammals and reptiles, could not be identified to lower taxonomic levels. Important prey were rabbits (33% by number), dragon lizards (29%) and juvenile kangaroos (6%). Dietary proportions were similar at the two nests, except for the relative number of birds taken (9% vs 3%). No lambs were recorded as food. Assumed or estimated masses were 1.5 kg for rabbits, 5 kg for kangaroos and fox, kg for unidentified mammals, 0.5 kg for birds and unidentified (small) items, and 0.4 kg for reptiles. On this basis, mammals contributed 77 percent of dietary biomass (rabbits 45%, kangaroos 26%), birds 3 percent and reptiles 12 percent (calculated from Table 4).

The three prey categories (mammals, birds and reptiles) appeared in the nestling diet throughout each of the seven weeks of observation up to fledging, except that at Nest 2 birds appeared only in the final two weeks, and reptiles peaked in the final week.

Prey remains found under eagle nests included Galah *Cacatua roseicapilla*, lizards and juvenile kangaroo at the two observed nests; Emu *Dromaius novaehollandiae* chick, crow *Corvus* sp. (cached in the nest tree), rabbits, juvenile kangaroos and Bearded Dragons at other active nests in 1997; and rabbits, juvenile kangaroos, Goat *Capra hircus* hindleg and Bearded Dragons among old remains at unused nests in 1997 or at a nest used in 1996. No lamb remains were found.

The adult eagles ate some prey remains by swallowing them whole at the nest. They also removed old food remains from both nests, particularly the carcasses of juvenile kangaroos.

TABLE 3

Parameters of nest trees for active and inactive Wedge-tailed Eagle nests at Fowlers Gap: mean ± standard deviation. Parameters and conventions as in Table 1.

Parameter	Active (9)	Inactive (30)
Nest height (m)	9.8 ± 3.7 (3.3–15.3)	5.1 ± 3.1 (1.5–12.5)
Nest position (%)	66.8 ± 13.3 (44.8–92.4)	59.2 ± 16.0 (35.0–100)
Tree height (m)	14.4 ± 4.1 (7.3–19.8)	8.3 ± 4.0 (4.3–16.5)
Crown depth (m)	12.1 ± 4.4 (5.6–19.0)	5.2 ± 4.7 (0.8–14.5)
Crown cover (%)	82.6 ± 10.3 (79.3–96.2)	71.3 ± 21.9 (6.3–90.0)
Crown area	129.9 ± 84.8 (40.6–265.5)	49.8 ± 77.0 (3.4–253.0)
Tree density (n/ha)	1323.3 ± 1193.6 (184.3–2332.9)	1151.7 ± 2142.1 (39.7–9457.6)
Tree condition	3.2	2.7

TABLE 4

Prey items brought to two Wedge-tailed Eagle nests at Fowlers Gap, nestling period, August–October 1997 (from video surveillance of nests; see text). Kangaroos were all young at foot. 'Other' includes indeterminate vertebrate carcasses.

Species	Nest 1	Nest 2	Total	%
Rabbit *Oryctolagus cuniculus*	35	28	63	33
Kangaroo *Macropus* sp. (juvenile)	6	5	11	6
Fox *Vulpes vulpes*	1	0	1	<1
Unidentified mammal	2	7	9	5
Total mammals	44	40	84	44
Unidentified bird	9	3	12	6
Central Bearded Dragon *Pogona vitticeps*	27	28	55	29
Unidentified reptile	4	6	10	5
Total reptiles	31	34	65	34
Other (unidentified)	21	10	31	16
Total	105	87	192	100

TABLE 5

Average frequency of parental behaviours (n bouts per 100 hours of video time) at two Wedge-tailed Eagle nests at Fowlers Gap, in the nestling period (weeks 4–11). Feeding chicks includes tearing prey; greenery = leafy branchlets (nest lining). Nest 1 had two chicks, Nest 2 had one chick.

Behaviour	Nest 1	Nest 2
Deliver prey	17	14
Feed chick(s)	89	110
Preen chick(s)	27	62
Brood chick(s)	6	17
Shade chick(s)[a]	18	1
Bring greenery	35	18
Remove old food	10	8

[a] Nest 1 exposed, on dead part of tree (at 71% tree height, with 8.25 m crown depth, 60% crown cover, 79 m^2 crown area); nest 2 sheltered (at 55% tree height, with 10.75 m crown depth, 81% crown cover, 165 m^2 crown area)

Parental time-budgets

Most of the behaviours recognised by Brooker (1974) and Ellis (1979) were observed in the adult Wedge-tailed Eagles at Fowlers Gap. The most frequent parental behaviour was tearing food and feeding the chick(s) (Table 5). Prey-delivery rates averaged 17 per 100 hours at Nest 1 (two chicks), and 14 per 100 hours at Nest 2 (one chick), or about 2.2 and 1.8 items per 13-hour day respectively. Preening and brooding the chick(s) was more frequent at Nest 2 than Nest 1, whereas the converse applied to shading the chick(s) and delivering sprays of green leaves. The single chick was brooded three times as often as the brood of two. Food was brought in the bill or feet; greenery was mostly carried in the bill, but sometimes in the feet.

The proportion of observation time spent in various parental activities was similar at the two nests: tearing food and feeding young 6.6–6.8 percent; brooding 1.3 percent at Nest 1, 3.1 percent at Nest 2; shading 0.9 percent at Nest 1, 0.1 percent at Nest 2. At Nest 1, one parent was present for 28 percent of observation time, both parents present for 1 percent and both absent for 71 percent; the figures for Nest 2 were 32, 1 and 67 percent respectively. At Nest 2, the male parent was in brown immature plumage and easily distinguished from the mature female; he delivered most of the food and only occasionally fed the chick. At Nest 1 the mature adults were similar in appearance and difficult to distinguish on videotape, so sex roles could not be ascertained.

At Nest 1, feeding of chicks peaked in the early morning and late afternoon; deliveries of greenery showed a similar but less pronounced pattern. At Nest 2, feeding of the chick showed a minor peak in early to mid morning and strong peaks in mid and late afternoon; deliveries of greenery peaked in the early morning, with few in the middle of the day (especially) and afternoon. Prey was delivered throughout the day at both nests (Figure 1). Preening and brooding of chicks peaked at the end of the day, whereas shading the chicks peaked from mid-morning to early afternoon (Figure 2). Shading was more prevalent at Nest 1, which was located on a dead section of the tree, than at Nest 2, which was surrounded by dense foliage (Table 5). (Nest 1 may have been built when the section of tree was alive.)

Brooding of chicks in Nest 1 declined from a peak at the start of observations (in week 4 of the nestling period) to cessation in week 7. Conversely, shading of chicks peaked in weeks 6 and 7 when chicks were still downy, and continued sporadically until week 10 (Table 6). The maximum duration of shading (0.5–1 hour per day on some days in weeks 6 and 7) occurred when daily temperatures peaked at 28–36 degrees. Feathered young were not shaded by the parent in their final week, even when the temperature exceeded 35 degrees. At Nest 2, brooding continued sporadically until the chick was nearly fledged.

The proportion of parental time spent at the nest declined steadily through the nestling period, from about nine hours per 13-hour day early in week 4 to less than two hours per day on most days in the final two weeks. The parental food-delivery rate (as measured by number of items delivered) remained constant throughout the nestling period. Tearing of food for chicks declined through the nestling period, although parents sometimes tore food until fledging. There was no apparent change in prey size over time, except that the relative number of birds and reptiles (i.e. small prey) peaked in the final week at Nest 2. Deliveries of greenery peaked in weeks 5–7 then declined from week 8 at Nest 1 (two chicks), but were constant at a lower rate through the nestling period at Nest 2 (Tables 6 and 7).

Nestlings

Nestlings performed many of the behaviours described by Ellis (1979). At Nest 1, the first chick hatched on 23 August and the second chick one day later. No siblicidal behaviour was observed after monitoring started (in week 4), but an advanced nestling sometimes aggressively took prey from a parent or sibling and mantled over the food with its back to the other bird(s). The older nestling at Nest 1 first ventured off the nest at 72 days old (day 73 post-hatching, from videotape), though this event does not equate with first true flight from the nest tree as the eaglet may have been a 'brancher' in the nest tree for several days.

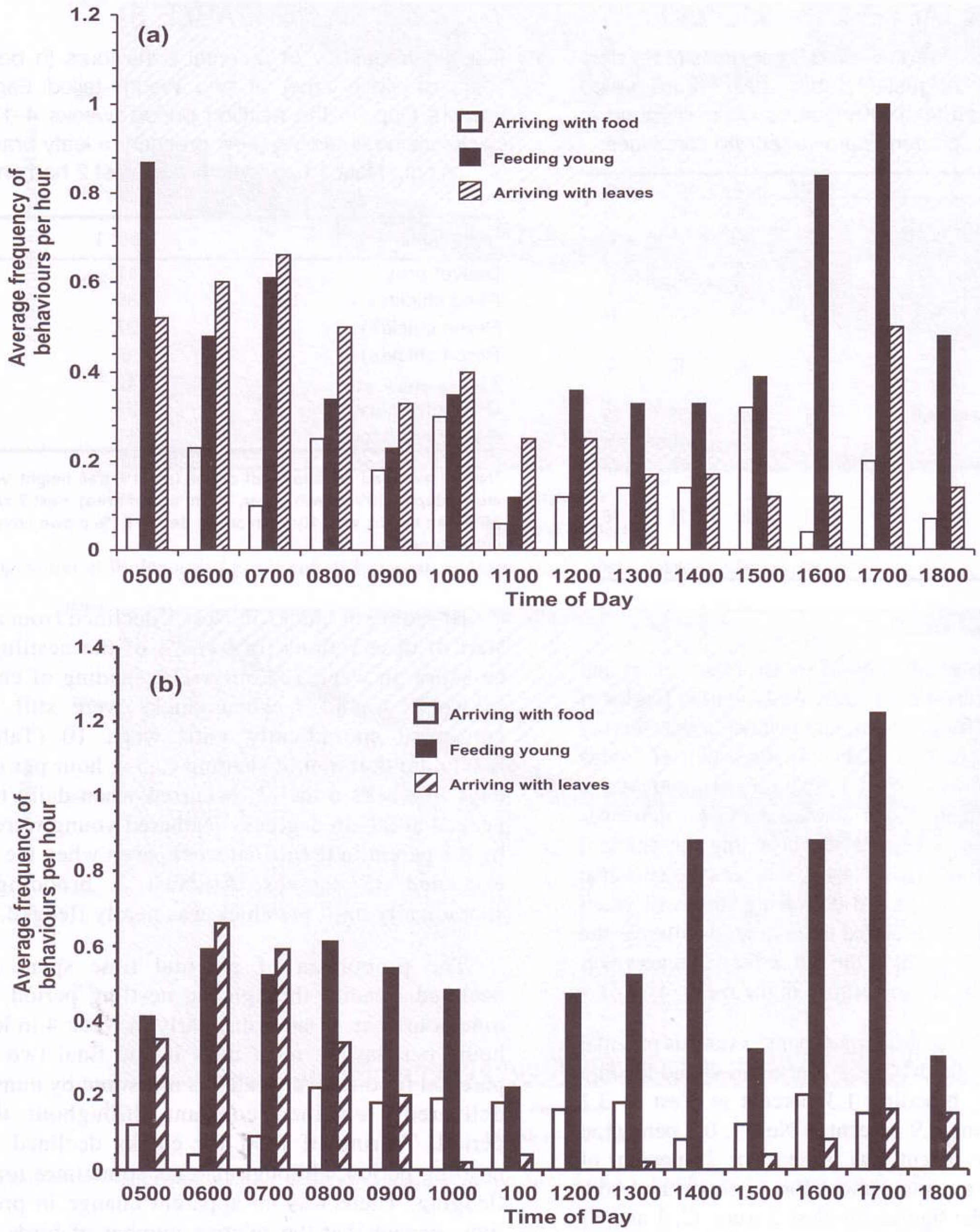

Figure 1. *Average hourly frequency of prey delivery, feeding of young and foliage delivery by time of day at two Wedge-tailed Eagle nests in western New South Wales, in weeks 4–11 of the nestling period: (a) Nest 1; (b) Nest 2.*

Response to the research method

The first three attempts to monitor the eagles by remote video surveillance were initiated just after the eagles laid eggs. The birds often flushed from the nest and the setting-up activities prevented them from incubating, thus probably chilling the eggs. One pair deserted, and two incubated beyond the normal period of about 45 days (Marchant and Higgins 1993) before failure to hatch. A fourth installation attempt was made at the pipping stage, but set-up activity disturbed the eagle late in the day and it did not incubate overnight, thus leading to chilling and hatching failure. The final two attempts at video-monitoring resulted in acceptance by the adults and successful fledging of chicks: one camera positioned during incubation but recording not activated until the nestling period, and one installed during the nestling period.

DISCUSSION

Clutches of two eggs at Fowlers Gap are consistent with previous data on clutch size in the Wedge-tailed Eagle (reviewed by Marchant and Higgins 1993). Breeding success (fledglings per clutch) at Fowlers Gap in 1997 was lower than recorded elsewhere in Australia (cf. Marchant and Higgins 1993), but was depressed by human disturbance at nests. The hatching interval at Nest 1 was shorter than expected from a laying interval of probably 2–3 days for this species, incubation starting with the first egg, and asynchronous hatching (cf. Marchant and Higgins 1993).

Nest dimensions and nest-site characteristics were similar to those previously described for the Wedge-tailed Eagle, particularly in the arid zone where trees are small and the range of site options is limited (cf. Marchant and Higgins 1993 and

TABLE 6

Parental behaviour at two Wedge-tailed Eagle nests, Fowlers Gap, through the nestling period (weeks 4–11): percent of observation time in each week. Absent = both adults away from nest; both present = both adults on nest; feeding includes tearing food.

Week (h obs.)	Brood	Absent	Both present	Feed chick	Shade
Nest 1:					
4 (41.2)	10	52	<1	13	<1
5 (87.8)	2	54	<1	12	<1
6 (91.3)	<1	57	2	10	3
7 (94.5)	<1	64	1	9	1
8 (94.5)	0	70	<1	6	<1
9 (94.5)	0	95	<1	2	<1
10 (81.3)	0	86	0	2	<1
11 (34.7)	0	99	<1	0	0
Nest 2:					
4 (36.7)	9	59	<1	14	0
5 (87.2)	4	65	1	9	0
6 (83.5)	6	49	2	10	0
7 (80.5)	5	62	1	8	0
8 (88)	<1	69	2	4	0
9 (94.5)	2	76	1	3	0
10 (94.5)	<1	77	1	3	<1
11 (36.9)	1	77	1	2	0

TABLE 7

Parental activity at two Wedge-tailed Eagle nests, Fowlers Gap, through the nestling period (weeks 4–11): frequency of behaviours (n instances per hour) in each week.

Week (h obs.)	Bring prey	Bring greenery	Remove food
Nest 1:			
4 (41.2)	0.2	0.3	0.1
5 (87.8)	0.1	0.5	0.1
6 (91.3)	0.3	0.5	0.1
7 (94.5)	0.2	0.6	0.1
8 (94.5)	0.2	0.4	0.1
9 (94.5)	0.1	0.1	0.1
10 (81.3)	0.2	0.1	0.1
11 (34.7)	0.2	0.1	0
Nest 2:			
4 (36.7)	0.2	0.1	0.1
5 (87.2)	0.2	0.2	0.1
6 (83.5)	0.1	0.1	0.1
7 (80.5)	0.1	0.1	0.1
8 (88.0)	0.1	0.2	0.2
9 (94.5)	0.1	0.2	0.1
10 (94.5)	0.2	0.2	0.1
11 (36.9)	0.2	0.1	0.1

studies cited therein; Sharp *et al.* 2001). At Fowlers Gap, nests were lower in smaller trees, and in lower positions in the tree, on ridges than in creeks, probably because nests in Mulgas (which are small trees) had to be placed in sturdy basal forks or the nests needed more crown cover on such exposed sites. On ridges, the eagles nevertheless selected taller trees among those available. These results are similar to those of Sharp *et al.* (2001) for the same region, allowing for different tree species in the different habitats studied.

Where possible (i.e. on creeks), the eagles at Fowlers Gap selected taller (emergent) trees with larger crowns from among those available, probably because height and cover confer advantages for access, vigilance, security and shelter. It appeared that by 1997 (post-calicivirus), eagle breeding activity had contracted to the most productive areas of the landscape (i.e. creeks), because pairs had ceased breeding in, or perhaps had abandoned, ridge territories that may be of lower quality. These nests on ridges may also have been abandoned after the nest tree died, if a lack of canopy renders the nest unsuitable for breeding or unsuccessful because the nest is exposed. Ridpath and Brooker (1987) found no evidence that Wedge-tailed Eagles selected nest trees on the basis of condition, species or height in habitats similar to those of this study, because suitable trees were readily available at their study sites. Sharp *et al.* (2001) concluded that eagles show no selection for particular tree species, and build in the most common tall trees available: a result consistent with the present study.

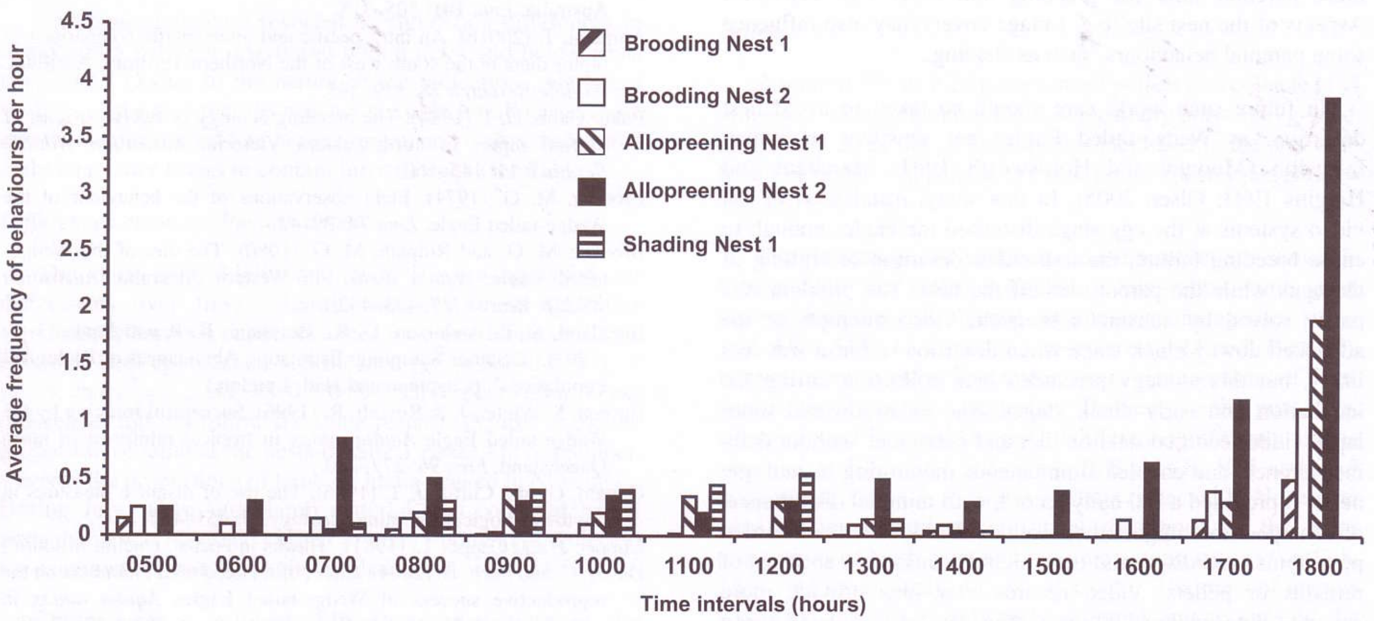

Figure 2. *Average hourly frequency of brooding, allopreening the young and shading the young by time of day at two Wedge-tailed Eagle nests in western New South Wales, in weeks 4–11 of the nestling period.*

The diet of the eagles at Fowlers Gap was similar to that elsewhere in the arid zone, and particularly in western New South Wales, including the eagle's dependence on rabbits, lizards and juvenile kangaroos (cf. Leopold and Wolfe 1970; Brooker and Ridpath 1980; Baker-Gabb 1984; Robertson 1987; Richards and Short 1998; Falkenberg *et al.* 2000; Aumann 2001b; Sharp *et al.* 2002a). Rabbits were still prevalent in the diet at 'creek' nests a year after the arrival of the calicivirus. Juvenile kangaroos were most abundant on the rolling downs at the onset of the eagles' breeding season, but remained similarly abundant through the nestling period. Although a minor dietary component by number, they provided substantial prey biomass. Although lambs were available and more than twice as abundant as juvenile kangaroos, the eagles did not take lambs. Fewer birds were taken at Fowlers Gap than were reported taken in many other studies (cited above, and by Marchant and Higgins 1993). Eagle breeding at Fowlers Gap is likely to coincide with peak abundance of suitably sized prey (i.e. juvenile kangaroos), which would enable adult eagles to attain the body condition required for breeding (Olsen 2005).

Parental behaviour of the eagles at Fowlers Gap was as described anecdotally for this species (Marchant and Higgins 1993; Fleay-Thomson 2002; Allott *et al.* 2006), similar to the results of Harder (2000), and generally as described for other large *Aquila* species. Patterns include a decline in nest attendance and parental care as nestlings mature and achieve thermoregulation (cf. Ellis 1979; Gargett 1990; Watson 1997; Olsen 2005). Inter-nest differences in some behaviours at Fowlers Gap may have been partly related to brood size, although there was also some individual variation in the daily pattern of some behaviours. Two chicks may have necessitated greater attention to food provision and nest maintenance or hygiene (greenery), whereas a single chick may have necessitated greater attention to preening and brooding because two chicks can preen each other and huddle together for warmth. The smaller food demands of a single chick may leave more parental time for preening and other nest activities. Aspects of the nest site (e.g. foliage cover) may also influence some parental behaviours, such as shading.

In future such work, care should be taken to avoid nest desertion, as Wedge-tailed Eagles are sensitive to human intrusion (Mooney and Holdsworth 1991; Marchant and Higgins 1993; Olsen 2005). In this study, installation of the video systems at the egg stage disturbed the eagles enough to cause breeding failure, through either desertion or chilling of the eggs while the parent was off the nest. The problem was partly solved by starting subsequent video attempts at the advanced downy chick stage when desertion or harm was less likely, but this strategy precluded data collection during the incubation and early chick stages. The solar-powered time-lapse video recorded data on diet and behaviour without daily interference, and enabled simultaneous monitoring of multiple nests. It provided a full daily record, with minimal disturbance, of behaviour that might otherwise be missed, and also recorded prey items (and disposals) that might be missed in analyses of remains or pellets. Video records may also provide more accurate data on prey biomass than can be calculated using traditional analyses. However, one-third of prey items in this study were unidentified or not identified below class level.

Given the sensitivity of the Wedge-tailed Eagle to disturbance, installation of cameras or other intrusive activities should be avoided during the prelaying, incubation and early chick stages, when observations could be conducted by telescope from beyond the eagles' alarm zone (or from a hide). Camera installation during the nestling phase should be conducted 2–3 weeks after hatching, and installation should be conducted in mid-morning in mild conditions, and suspended for 3–5 days if more than an hour is required to complete the process, to minimise the risk of chick exposure to weather or predators. Dummy cameras could be installed at many prospective nests, well in advance of the breeding cycle, and replaced with real cameras when the eagles are safely established. Colour, rather than monochrome, equipment may also be an advantage for distinguishing the sexes and identifying prey. Finally, preliminary nest observations from a hide may enable familiarisation with local prey species, and thus reduce the incidence of unidentified prey items on video footage.

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Adult male perching below nest.