Breeding productivity of the Wedge-tailed Eagle *Aquila audax* on the Fleurieu Peninsula, South Australia in 2017

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Obtaining data on the reproductive rates of raptors is helpful in assessing the status of raptor populations and the factors that influence it. Breeding productivity of the Wedge-tailed Eagle, *Aquila audax* on the Fleurieu Peninsula was studied in 2017 and the results were compared with data recorded in 2005. We visited all 44 active territories in the survey area on multiple occasions and gathered eagle reproductive data. In total, 38 pairs successfully fledged young, with 10 pairs (26%) fledging two young. Fledging productivity was 1.1 young/active territory, 1.3 young/successful territory; it resembled that recorded in 2005. Egg laying and hatching dates were calculated for 30 active territories, with the egg-laying period extending over 107 days (mid-June to late September, most laid by late August). Two pairs fledged young late at the end of January 2018, but 98% of pairs had fledged young by the end of December 2017.

INTRODUCTION

Breeding productivity of the Wedge-tailed Eagle, *Aquila audax* (WTE) has been studied in various parts of Australia recently (Dennis 2006a; Collins and Croft 2007; Debus *et al.* 2007; Fuentes *et al.* 2007; Parker *et al.* 2007; Silva and Croft 2007; Cherriman *et al.* 2009; Wiersma and Koch 2012; Cherriman 2013). Studying the reproductive rates of raptors can be valuable in assessing the status of raptor populations and the factors that influence it. These studies are important for identifying effective conservation measures for threatened and declining species (Steenhof and Newton 2007).

The Fleurieu Peninsula WTE population is thought to have suffered declines at various times in the past (Paton *et al.* 1994), and a baseline population survey was performed in 2005 (Dennis 2005, 2006a) to establish the status and distribution of this iconic Australian raptor in the region. The present study forms part of a larger project which is a systematic re-surveying and assessment of the status and distribution of the species on the Fleurieu Peninsula more than ten years after the original baseline survey (Rowe *et al.* 2018, in prep). To determine the stability of the population and investigate whether breeding parameters had changed, we studied reproductive success as part of the larger project in 2017. All territories studied in 2005 were re-examined and additional territories located were included. This paper reports the data collected on breeding productivity and chronology in 2017, providing a comparison with those recorded in 2005. Comparative reproductive data for populations in different years are valuable, as they may reflect differences in land use, contaminant levels, human activity, or variations in natural phenomena, such as weather or prey supply (Steenhof and Newton 2007).

STUDY AREA AND METHODS

Survey area

The Fleurieu Peninsula is the area to the south and west of a line between Port Willunga (35°16'S, 138°28'E) and Goolwa (35°30'S, 138°47'E). However, as in the 2005 survey, to cover likely overlapping WTE territories, a small area of the northern Sellicks Hill Range and Southern Mount Lofty Ranges was included by arcing the survey boundary inland to the northeast by approximately 5 km, resulting in a survey area of approximately 1540 km^2. All active breeding territories located in this extensive survey (Rowe *et al.* 2018, in prep.) were studied, gathering data on reproductive variables and breeding success. This information was directly compared with the 2005 survey findings. Background information for the 2017 survey was directly available through accessing precise (GPS) nest-site location data gathered during the extensive surveys of 2005 and 2006 (Dennis 2005, 2006a, b). A scientific research permit (number Q26620-1) was issued for the research by the South Australian Department of Environment, Water and Natural Resources.

Survey timing and strategies to minimise disturbance

From January 2017 to January 2018 all WTE territories located in the 2005 survey and additional territories (found during prospective habitat searching in the larger project mentioned above) were visited on multiple occasions. During this period, extended observations of 44 confirmed active territories were made throughout the survey area from suitable vantage points using binoculars to minimise disruption to normal behaviours. Actual nest location and approaching the nest were deliberately postponed until mid-October (through to December) when active nests contained developed young, hunting and prey-carrying flights were frequent and obvious, and sensitivity to approach had lessened. When nest sites were located, observation of nest contents was conducted from a distant elevated position (Rowe *et al.* 2018, in prep). When nest sites were approached, data-gathering time was minimized (<5 min) and the area vacated as soon as possible to allow the adults to resume normal behaviour (Olsen 2005).

Terminology

Two key terms used throughout this study are defined as follows:

Active nest or territory: includes where incubation behaviour is observed, where young are present, and where a pair was observed at least twice in a prey- or stick-carrying flight and repeated fast and direct low-level flight toward a freshly lined nest with accumulated faecal spray present.

Successful nest or territory: where fledged young are recorded.

Habitat disturbance

To be consistent with earlier surveys, as part of the larger survey each active territory was assessed for likely disturbance factors and proximity to human activities (Rowe *et al.* 2018, in prep). This included assessment of: [1] the intensity of agricultural and/or horticultural activities nearby, [2] proximity to roads, tracks and walking trails, [3] occurrence of recreational activities, [4] presence of overhead power transmission lines, and [5] proximity to proposed wind-farm developments, residences or other occupied infrastructure (Dennis 2005). This information was used in this part of the study when identifying factors potentially influencing reproductive success. Based on this information, territories were classified as having:

Low disturbance — when the nest site was in a relatively remote setting e.g. no roads, tracks, walking trails or dwellings within 500m; nest was not visible from such features; few people were likely to approach the nest-site during the breeding season.

Moderate disturbance — when the nest site was in a 'semi-remote' setting; people may gain access within photography or missile range; roads, tracks, walking trails or dwellings occur within 500m from nest; nest is visible from such features; some people, vehicle or machinery movements occurred within 500m of the nest site during the breeding season.

High disturbance — when the nest site was in a relatively disturbed or developed setting; nest was clearly visible from roads, tracks, walking trails or dwellings; frequent movements of people, vehicle or machinery occurred within 500m and in full view of nest during breeding season.

RESULTS

Breeding productivity

Breeding productivity data were obtained for all 44 active territories. The total number of fledged young was 48. Thirty-eight pairs successfully fledged young, with 74% (28 pairs) fledging a single young and 26% (10 pairs) two young. Single or paired young were recorded as fledged when they were seen to be close to the nest site (n = 12 territories); 'branching' i.e. fully feathered and actively wing-exercising young on the nest platform or nearby branches (n = 10 territories), or flying with both adults in a known occupied territory (n = 12 territories). Death of a sibling was recorded for two of the pairs observed successfully raising one young (FP34, FP12). Six localities (67%) contained territories from which two young fledged: four (44%) of these localities had one territory, one (11%) had two territories, and one (11%) had four territories.

Three pairs (FP02, FP24, FP52) failed to fledge young. Two of these pairs lost one young during the nestling period (FP02, FP52) and one pair deserted the nest during incubation (FP24). Productivity data could not be obtained for three active territories where either the breeding outcome was unknown (FP38, FP46) or incubation was not confirmed (FP14). Combining the data, fledging productivity was 1.1 young per active territory (n = 44) and 1.3 young per successful territory (n = 38); this can be compared with the 2005 figures of 0.91 young/active territory (n = 23) and 1.11 young/successful territory (n = 19) (Dennis 2005) (Table 1).

Breeding season

Egg laying and hatching dates were calculated for active territories in which the fledging or 'branching' dates were known (n = 30). Young that were 'branching' were considered ~77 days old and young that had fledged (seen near the nest or on the wing) were considered to be ~ 84 days old (Debus 2017; S. Debus pers. comm.). An incubation period of 42–43 days was deducted from the estimated hatching dates to obtain approximate egg-laying dates (± 5 days) for each clutch (Debus 2017; S. Debus pers. comm.).

Applying this method, egg-laying commenced on or about 14 June 2017 and finished on or about 26 September 2017. Two pairs laid eggs in late September, but 98% (28 pairs) had laid their eggs by the end of August. The egg-laying period in the study area extended over 107 days. Hatching commenced on or about 28 July 2017 and finished on or about 7 November 2017. Hatching occurred in August and September in 24 pairs (80%), late July in two pairs (6.7%), early October in two pairs (6.7%) and early November in two pairs (6.7%). The earliest fledged young were recorded on 18 October 2017 and the last fledged young on 30 January 2018. Twenty-eight pairs (98%) had fledged young by the end of December (n = 28) and two pairs (2%) fledged young on 30 January 2018 (Table 2).

Habitat disturbance and breeding success

Of the three active territories that failed (FP02, FP52, FP24), two were rated as being in a high and one in a moderate disturbance area. Six active territories (75%) with a high disturbance rating were successful, nine (90%) with a moderate rating were successful and all twenty-three (100%) with a low disturbance rating were successful (excluding FP40 which was active, but incubation was not confirmed) (Table 1). Productivity was 1.2 young/successful low disturbance rated territory (n=23), 1.2 young/successful moderate disturbance rated territory (n=9), and 1.5 young/successful high disturbance rated territory (n=6).

DISCUSSION

Breeding productivity

In the 2017 breeding season, fledging productivity was considered average to high and resembled the productivity recorded in 2005. In 2017, ten pairs fledged two young, compared with two pairs in 2005. These productivity data resemble the fledging rates recorded near Canberra, ACT in the 2002–2003 season (1.2 young per active territory, 1.4 young per successful territory, 30.6% of territories fledging 2 young [n=44 territories]), which were higher than those found in other studies in that area (Fuentes *et al.* 2007). They are also higher than the values reported for other recent studies in the temperate and arid agricultural and pastoral zones of southern Australia (cited in the Introduction above, and reviewed by Debus 2017). Fuentes *et al.* (2007) concluded that permanent water near most nests and a permanent supply of macropods contributed to the high productivity in that study. Ridpath and Brooker (1986) showed that low eagle breeding success in certain areas was linked to low rainfall and low rabbit numbers. The WTE does have great

Table 1

Location, productivity and disturbance rating of active Wedge-tailed Eagle territories on the greater Fleurieu Peninsula in the 2005 and 2017 breeding seasons.

Locality	No. successful territories		No. young fledged		Disturbance Rating 2017§		
	2005†	2017§	2005†	2017	Low	Med	High
Southern coastal area (Goolwa to Cape Jervis)	3	11	3	13	9	2	2
Western coastal area (Cape Jervis to Normanville)	4	5	4	5	4	–	3
Western coastal area (Carrickalinga to Port Willunga, including Sellicks Hill Range)	1	3	1	4	2	2	2
Yankalilla River catchment	2	5	2	6	4	–	2
Myponga River catchment	1	1	1	1	1	1	–
Hindmarsh River catchment	1	4	2	5	3	1	–
Inman River catchment	5	7	5	11	4	5	1
Currency Creek catchment	1	1	1	1	1	–	2
Finnis River catchment	–	1	–	2	–	–	1
Total No:	18*	38‡	19*	48‡	28	11	13

* data taken from Dennis TE (2005)
† productivity outcome was determined for 22 active territories in 2005.
‡ productivity outcome for 44 active territories in 2017.
§ data taken from Rowe *et al.* (2018)

Table 2

Temporal span of the Wedge-tailed Eagle breeding season on Fleurieu Peninsula in 2017. The symbol 'H' represents the 3–5 day long asynchronous hatching period. A row of symbols '+' (at four "weeks" per month) indicates the approximate period from egg laying to fledging (± 5 days), determined by calculations made on known 'branching' (age estimated as 77 days) and fledging (age estimated as 84 days) dates.

Site	June	July	August	September	October	November	December	January
FP01	+	+ + + +	+ H + +	+ + + +	+ + + +			
FP30	+	+ + + +	+ H + +	+ + + +	+ + + +	+		
FP31	+	+ + + +	H + + +	+ + + +	+ + + +			
FP32	+	+ + + +	+ H + +	+ + + +	+ + + +	+		
FP33				+	+ + + +	H + + +	+ + + +	+ + + +
FP03		+ +	+ + + H	+ + + +	+ + + +	+ + +		
FP34		+	+ + + +	H + + +	+ + + +	+ + + +		
FP46		+	+ + + +	H + + +	+ + + +	+ + + +		
FP04		+ + +	+ + + H	+ + + +	+ + + +	+ +		
FP48		+ + + +	+ + H +	+ + + +	+ + + +	+ +		
FP08		+ +	+ + + H	+ + + +	+ + + +	+ + +		
FP09		+ +	+ + + H	+ + + +	+ + + +	+ + +		
FP10			+ +	+ + + H	+ + + +	+ + + +	+ + +	
FP50		+ + +	+ + + H	+ + + +	+ + + +	+ + + +		
FP42	+ + +	+ + + H	+ + + +	+ + + +	+ + +			
FP15			+	+ + + +	H + + +	+ + + +	+ + + +	
FP16		+ + +	+ + H +	+ + + +	+ + + +	+ + +		
FP17	+	+ + + +	+ H + +	+ + + +	+ + + +	+		
FP43			+ +	+ + + H	+ + + +	+ + + +	+ + + +	
FP18			+ + +	+ + + H	+ + + +	+ + + +	+ + +	
FP36			+	+ + + +	H + + +	+ + + +	+ + + +	
FP19		+	+ + + +	H + + +	+ + + +	+ + + +		
FP20		+	+ + + H	+ + + +	+ + + +	+ + + +		
FP21			+ + + +	+ + H +	+ + + +	+ + + +	+ +	
FP47			+ + +	+ + H +	+ + + +	+ + + +	+ +	
FP26		+ +	+ + + H	+ + + +	+ + + +	+ + +		
FP51				+	+ + + +	H + + +	+ + + +	+ + + +
FP41	+ + +	+ + + H	+ + + +	+ + + +	+ + +			
FP39		+ +	+ + + H	+ + + +	+ + + +	+ + +		
FP49		+ + +	+ + + H	+ + + +	+ + + +	+ + +		

flexibility with diet and can switch between prey types, but drought conditions could result in widespread prey decline (Olsen *et al.* 2014). In Australia, rainfall drives many natural processes (Barrett *et al*. 2007) and therefore 'good' rainfall may have had a positive effect on the productivity recorded in our study. There is probably a lag time between rainfall and changes in bird numbers (Barrett *et al.* 2007) and prey availability; thus, the annual rainfall in 2016 may have been significant for the 2017 breeding season examined in our survey. That year (2016) was one of the wettest on record, with many areas of South Australia experiencing higher than average rainfall, including the Fleurieu Peninsula, which had some record-breaking annual readings. For example, Parawa's annual rainfall was 1153mm in 2016 (long-term average 839.9 mm) and Victor Harbor's annual rainfall broke a twenty-year record with 1037.8 mm (long-term average 699.5 mm) (http://www.bom.gov.au/climate/current/annual/sa/archive/2016.summary.shtml#recordsRainTtlHigh). The territories in which two young fledged were spread over six different localities. The Inman River catchment locality registered the highest success rates, with four pairs fledging two young. This locality is close to Victor Harbour and the abundance of prey after the high rainfall may have been a factor in this success. However, prey availability is not always linked to rainfall patterns (Sharp *et al*. 2001), so other factors may have been involved.

Three WTE pairs in our study failed to fledge young, two losing one young during the nestling period (FP02, FP52) and one pair deserting the nest during incubation (FP24). The FP02 nest was in a high disturbance area, visually exposed and only 3m up in an *Allocasuarina* sp., with virtually no shade/cover. The female of this pair also laid her eggs late in the season, with a 3–5 day-old chick being seen in the nest on 6 October 2017 exposed to the harsh midday sun. Eagles usually use nest sites that shelter young from the afternoon sun (Foster and Wallis 2010) and thus the lack of shade during the nestling period late in the season may have contributed to breeding failure. Human intrusion is one of the main threats to the WTE throughout the breeding season (Debus 2017) and this nest did have a high probability of disturbance from human activity. The parents in this case may consequently have had to spend extended periods away from the nest, contributing to the loss of the chick and subsequent nest desertion.

Chick survival to fledging may be affected by both nest and parental quality (Collins and Croft 2007). Nest quality may encompass both nest and tree characteristics (e.g. cover and stability) in addition to nest location (i.e. in relation to prey densities), and growth may also be affected by sibling competition (Collins and Croft 2007). Parental quality may encompass the rate of nest attendance and parental care, provisioning rate and nestling diet composition (Collins and Croft 2007). The FP52 pair, which also lost one nestling, used a visually exposed nest in a high disturbance location. The FP24 nest that was deserted was also in a tree in an open, park-like setting, with regular farm activity occurring around it. It is unknown what resulted in these failures, but the location of the nests may have contributed.

No young were recorded in three of the active territories. The outcome of breeding was unknown in two of these territories. In the third territory, incubation could not be confirmed, although the territory was active because the nest was freshly lined (green leaves), had accumulated faecal spray present, and the pair dived directly into the nest location carrying prey/sticks on more than two occasions (Rowe *et al.* 2018, in prep.).

In this study, the death of a sibling was recorded in two territories in which another young was successfully raised. The FP34 nest had two young in it, with the larger one showing aggressive behaviour towards the smaller one, at 21 days of age. The smaller young was no longer present when the remaining one was 3-6 weeks of age. The FP12 pair had most likely laid a three-egg clutch; a broken egg was found below the nest before two small young were observed at a later date. Clutch size can vary from 1-3 eggs (mean 1.9), although usually there are two (Debus 2017). One of the young was either pushed or fell out of this nest at approximately 5 weeks of age, and the other successfully fledged. The decomposing carcass of the young that died was found near the nest and examined after its sibling fledged, and its age at death was estimated from feather eruption illustrated in Olsen (2005). The WTE is known to be facultatively siblicidal (related to prey abundance), but there is limited research on this topic for the species. Collins and Croft (2007) found that opportunity for siblicidal behaviour appeared to be related to the level of parental attendance, and was most intense during parental absence. It is not known exactly what led to this sibling's death, as there are obviously other causes of chick mortality besides starvation or siblicide (Collins and Croft 2007).

Breeding season

In this study, there were two territories in which eggs were laid very late in the season (around 26 September 2017). Such late laying dates have been reported as being possibly associated with the laying of replacement clutches (Dennis 2006a), but the beginning and length of the egg-laying season can vary anyway, tending to start earlier and extend longer in years when prey are abundant (Olsen 2005). The high productivity levels in our study may indicate such a situation. The two nests in which egg-laying dates were late were also unlikely to have been disturbed (based on their secluded location) and indeed young fledged from both. Most of the breeding pairs (98%) in our study area had laid their eggs by the end of August and the eggs of twenty-four pairs (80%) hatched in August and September. This is consistent with the findings of the 2005 survey, in which eggs were present in July-August, hatching occurred in August–September (rarely October), nestlings were present in August–December (rarely January) and fledging occurred in November-December (rarely January) (Dennis 2005, 2006a). This chronology is consistent with those for southern mainland Australia generally (reviewed by Debus 2017). It is important to note that the breeding season did commence earlier and finish later in 2017 than in 2005 and so the two instances of very late laying may simply reflect this timing.

Habitat disturbance and breeding success

Wedge-tailed Eagles are generally very sensitive to disturbance. They are timid and prone to desert the nest if disturbed during nest site selection or from the time of egg-laying until the nestling is a few weeks old (Olsen 2005). In this study, great care was taken to reduce the chance of researcher-induced desertion, including in the later stage of the cycle when human intrusion could potentially result in a branching fledgling to take an early flight before they have adequate strength and skill (Rowe *et al.* 2018, in prep). Several nests were close to human activity (Rowe *et al.* 2018, in prep), but there is evidence that WTE can habituate to routine agricultural activity and road traffic (Debus *et al.* 2007; Fuentes *et al*. 2007). For example, some of the successful territories had regular farming activity occurring close to the nest; in one case, the successful nest was in an open setting in a paddock cut for hay, with farm machinery passing directly underneath it during the nestling period.

The effect of disturbance depends on the nature and timing of the human activity. For example, for the WTE in Tasmania regular disturbance has been found to be less harmful than irregular disturbance and disturbance in extreme weather conditions more harmful because of physical exposure of the egg(s)/chick(s). Disturbance was also cumulative; thus, frequent light disturbance, such as that created bushwalkers, may negatively impact breeding more than heavy, more distant disturbance would (Mooney and Holdsworth 1991).

The negative effect of human disturbance may have been evident in our study. The failed nests were rated as being in high ($n = 2$) and moderate ($n = 1$) disturbance locations, whereas there were no documented failures in those territories rated as low disturbance. However, these are small sample sizes and 75% of the nests in high disturbance areas were successful, with three pairs fledging two young. Overall these findings are positive, and if WTE continue to adjust to human activity their future may be secure. However, regular population and productivity monitoring will be essential to ensure early detection of any possible decline.

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