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Phases and duration of the White-bellied Sea-Eagle *Haliaeetus leucogaster* breeding season in South Australia and the implications for habitat management

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With courtship and nest repair behaviours commencing in early May and late fledging events in early January, the endangered White-bellied Sea-Eagle *Haliaeetus leucogaster* population in South Australia exhibits a variable and protracted breeding season.

Analysis of events in 75 active territories spanning 21 breeding seasons, showed the majority of egg-laying occurred in July (64.0%), with a peak in the second week. A few egg-laying events were in June (9.3%), with the remainder through August and early September. Most young were fledged by late November, with late egg-laying events extending the potential fledging timeframe into early January. The mean duration from hatching to fledging in 12 territories averaged 83.1 days (range 80–88 days).

Haliaeetus spp. are prone to abandoning a nesting attempt early in the breeding season, with the period of greatest sensitivity and risk of abandonment for the White-bellied Sea-Eagle in South Australia extending from mid-May (intensive courtship) through incubation to mid-September (early nestling period). Habitat management prescriptions that include at least a seasonally imposed buffer zone refuge over breeding habitat, are advocated to mitigate further population declines among the White-bellied Sea-Eagle population in South Australia.

INTRODUCTION

South Australia (SA) has a small and somewhat isolated White-bellied Sea-Eagle *Haliaeetus leucogaster* breeding population relative to other parts of its continental range. In 2010, Dennis *et al.* (2011a) estimated the population at 70–80 pairs and provided evidence of substantial (22%) declines on the mainland, with the majority (79%) of the contemporary population found occupying offshore island habitats. It is likely that the declines found in mainland habitats has followed increased human activity and corresponding levels of disturbance at nesting sites (i.e. residential and tourism developments in rural coastal areas, and recreation activities inexorably penetrating remote coastlines), thus adversely affecting population recruitment (Dennis *et al.* 2011b).

In response to similar declines in Victoria and Tasmania, specific conservation strategies have been developed, i.e. the Flora and Fauna Guarantee Action Statement #60 (Clunie 2004) and the Threatened Tasmanian Eagle Recovery Plan 2006–2010 (Threatened Species Section 2006). In SA, the White-bellied Sea-Eagle was formally up-listed to *Endangered* status in 2008, and the development of specific habitat protection and site management strategies appear necessary to increase nest productivity and thereby arrest further decline (Dennis *et al.* 2011b).

Many long-lived eagle species, including the White-bellied Sea-Eagle and other *Haliaeetus* spp., are sensitive to disturbance during the breeding season and will abandon the nest (and the breeding attempt for the season) when disturbance occurs during the pre-laying phase or early incubation period (Romin and Muck 1999; Gonzalez *et al*. 2006; U.S. Fish and Wildlife Service 2007; Olsen 1998; Threatened Species Section 2006). This behaviour, and the evidence of low productivity among a large proportion of the population in SA (Dennis *et al.* 2011b), accentuates the importance of understanding the temporal parameters associated with the White-bellied Sea-Eagle breeding season when species management plans are developed.

This study furthers this process by determining the seasonality, duration and sensitivity of each phase of the breeding season, and examines the likely refuge requirements for White-bellied Sea-Eagle breeding habitat in South Australia.

METHODS

Breeding season commencement and nestling age assessment

Between 1985 and 1999, observational records of the onset of White-bellied Sea-Eagle breeding-season behaviours (e.g. courtship and nest repair activity) were routinely recorded in conjunction with a long-term nest productivity study on Kangaroo Island (Dennis *et al.* 2011b). That study also provided estimated age data for 60 nestlings for nests situated between 35°40'S and 36°04'S. Additional nestling age data were obtained from several sources, including: banding records from the Australian Bird and Bat Banding Scheme (ABBBS); dated photographic records from Kangaroo Island before 1985

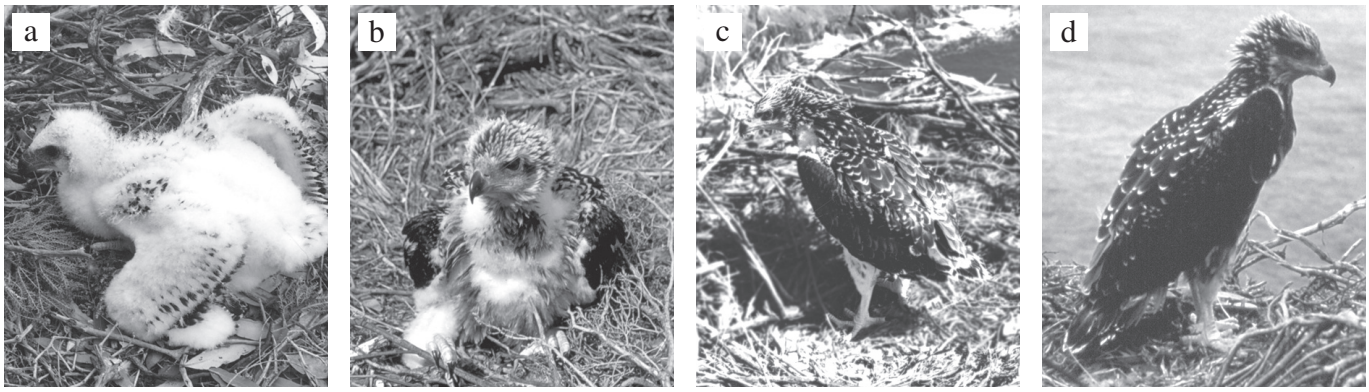

Figure 1. *Examples from the photographic index of known-age White-bellied Sea-Eagle young showing the various stages of feather development used in this study to estimate nestling age: a) 28–30 days; b) 42–44 days; c) 56–58 days; d) 70–72 days.*

(A.F.C. Lashmar unpubl. data); opportunistic records from surveys conducted on Kangaroo Island in 2005 (Dennis and Baxter 2006) and 2010 (Dennis *et al.* 2011a); observational notes and dated images collected on the Fleurieu Peninsula (35°37'S) in 1992, 1993, 1996, 2004 and 2008; the Riverland (34°15'S) in 2009, 2010 and 2011; from a dated photograph and banding record for Thistle Island (southern Spencer Gulf, 35°03'S) in 1974 (C. Gill *in litt.*); and a photographic record for southern Eyre Peninsula (34°43'S) in 1999 (K. Pobke *in litt.*); and from a small number of observation records obtained during coastal raptor population surveys between 2008 and 2011 in SA, which included one territory in the Far West region (32°01'S) (Dennis *et al.* 2011a). These data (n = 75) were collated and examined to determine the temporal homogeneity (or variation) in the commencement and duration of the White-bellied Sea-Eagle breeding season across South Australia.

The incubation period for the White-bellied Sea-Eagle is reported generally as being 40–41 days (Olsen 1995) and specifically, 40–42 days in northern New South Wales (Debus 2008). In this study, a 42-day incubation period was used and subtracted from the calculated hatching date (age one day = hatching date) to provide an estimated date of egg-laying.

Nestling age was estimated either at the time of banding, from direct observation by telescope, or by examination of dated photographic or digital images. Age estimates were based on a visual comparison of nestling feather eruption and development with a photographic index, consisting of a series of images of a known-age nestling taken at seven-day intervals from hatching to fledging at a nest on Kangaroo Island in 1960 (Figure 1). Allowing for incubation having commenced with the first egg and if produced, the second egg three days later (Marchant and Higgins 1993), and probable variation in prey availability and prey quality between territories (affecting nestling growth-rates), this age estimation method was considered accurate to ± 5 days. Temporal phases of the breeding season were calculated from these nestling age estimates.

Phases of the breeding season in an inland river-based territory

Frequent observations (by telescope) of a White-bellied Sea-Eagle nest site (i.e. nest in a dead tree surrounded by open water) and core territory area were made by one of us (GJF) throughout the 2009 and 2010 breeding seasons and into 2011, with behavioural sequences and events recorded.

Terminology

Key terminology is defined as follows:

- *Occupied territory* – an adult pair observed together during the breeding season in the vicinity of nest(s) and repairing the nest or defending the territory.
- *Active nest or territory* – a site where incubation behaviour suggests that eggs are present, or young are recorded.
- *Successful nest or territory* – fledglings are observed away from the nest.
- *Failed nest or territory* – where eggs fail to hatch, or where all eggs or young are lost.
- *Core territory* – the area around a nest site defended against intrusions by other eagles.
- *Guard-roosts* – strategic vantage points within the core territory used as day-roosts by the non-incubating bird.
- *Primary nest* – the most frequently used nest within a territory.
- *Alternative nest* – one of sometimes several nest structures within a territory.

RESULTS

Breeding season commencement

Apparent courtship, or pair-bonding flight displays (synchronised soaring) and vocalisation (duetting) displays occur throughout the year (Marchant and Higgins 1993). Long-term observation records from Kangaroo Island, nearby Fleurieu Peninsula, the River Murray and on several offshore islands, show that courting behaviours become more frequent from mid-April onwards and by mid-May include stick carrying flights and nest repair activity. These behaviours continue through June, with pairs spending increasing amounts of time within the core territory and attending the nest each day, irrespective of whether egg-laying follows.

The temporal span of 21 breeding seasons were assessed between 1960 and 2011 by examination of available data and images from 75 active territory events across SA (Figure 2) enabling an approximate egg-laying date to be calculated for each. Most eggs were laid in July (64.0%, n = 48) with a peak

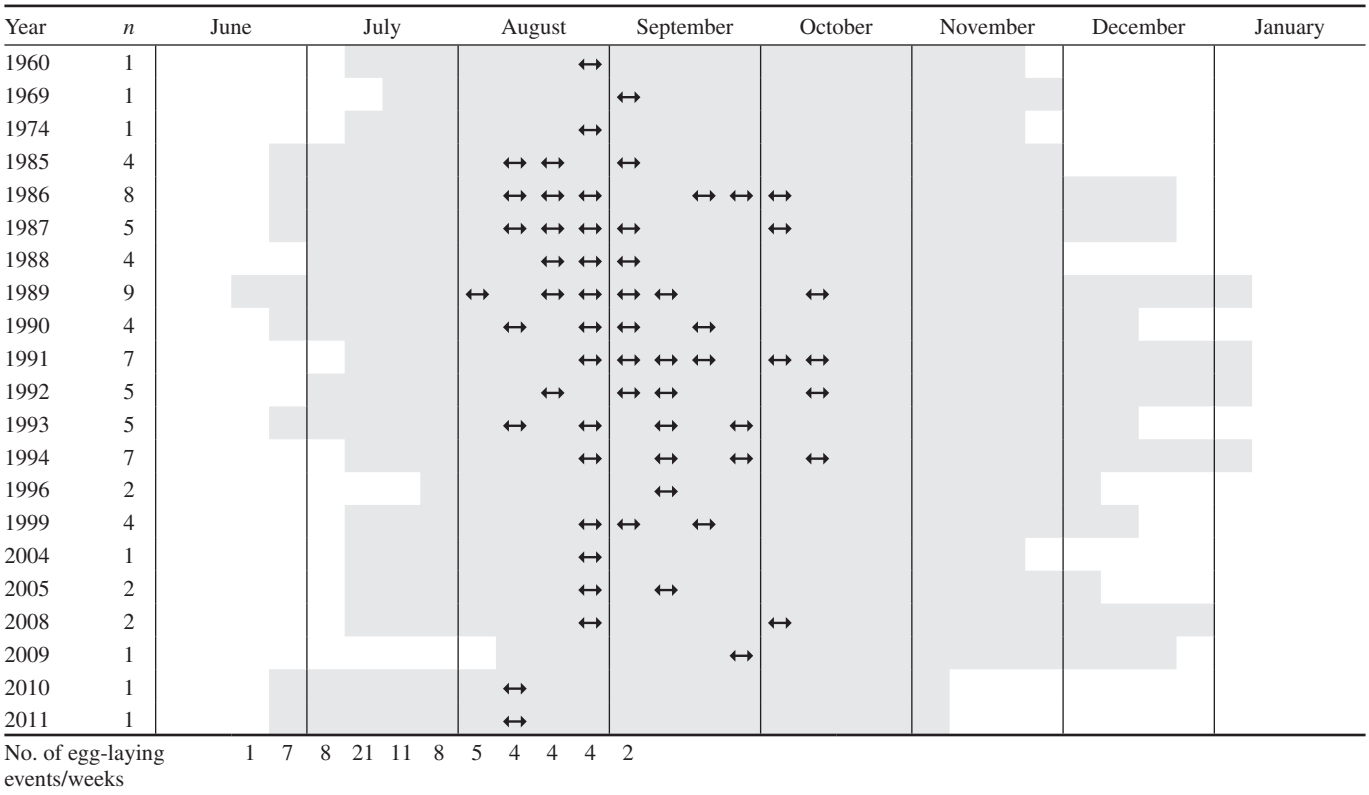

Figure 2. *Diagrammatic representation of 75 White-bellied Sea-Eagle breeding season events in South Australia between 1960 and 2011. The shaded area represents egg-laying to fledging, the symbol '↔' represents one or more hatching period ('week') and 'n' is the number of territories sampled.*

occurring in the second week (28%, $n = 21$). A few egg-laying events were earlier in June (9.3%, $n = 8$), with the remainder spread evenly through August (22.7%, $n = 17$) and early September ($n = 2$).

The actual timeframe when territories became active (egg-laying) varied between years and no discernible pattern found between neighbouring territories within years. Also, no obvious clinal variation was found in the onset of breeding across SA between 32°01'S (Far West coastal region) and 36°04'S (south coast of Kangaroo Island).

Hatching to fledging

Between 1960 and 1999 on Kangaroo Island, fledging dates were determined in eight territories where the date of egg-laying and hatching had been calculated. These provided estimated nestling periods of 80, 85, 85, 82, 84, 83, 80 and 82 days respectively. When data from the Fleurieu Peninsula in 1992 (84 days), 1993 (82 days) and 2008 (82 days) and the upper-Murray in 2010 (88 days) are included ($n = 12$), these provide an estimate of mean duration from hatching to fledging of 83.1 days ± 1.7 (s.d.), range 80–88 days.

Phases of the breeding season in an inland river-based territory

In 2009, courtship behaviours (including copulations) and nest-building activity began in early May; incubation was observed in late June but ceased after four weeks (presumed to have failed); incubation behaviour again recorded in mid-August; from the changed stance and behaviour of the female at the nest hatching was presumed in late September, 42–43 days after incubation commencement (i.e. 15 August to 27 September); female observed offering prey morsels below the nest rim on subsequent days; nest deserted in mid-October (young presumed to have died). The nest tree was uprooted in a severe windstorm in November 2009.

In 2010 stick-carrying flights and nest building commenced in a previously favoured perching tree in early April and continued through May, with a deep nest-cup formed by the end of the month; incubation commenced in the last week of June, during which the male undertook all nest provisioning and shared short periods of incubation, with remaining time at a favoured perch tree (guard-roost) in view of the nest approximately 300 metres distant; hatching occurred in the first week of August, 42–43 days after presumed commencement of incubation (i.e. 25 June to 5 August); single young standing on nest-rim wing-exercising in early October and branching with short hop-flights back to the nest by the end of the month; fledging occurred in first week of November approximately 88 days after estimated hatching date (i.e. 5 August to 2 November); fledgling observed hunting (prey pursuits) alone in natal area in mid-January (i.e. two months after fledging).

In January 2011 the nest was dislodged and lost during a severe windstorm. Subsequently stick carrying and placement behaviours at the same tree fork commenced in late March and continued periodically through April with the nest completely re-built by the end of May. Apparent egg-laying (incubation behaviour) commenced 22 June and hatching occurred c.43 days later on 3 August, again determined from female behaviours.

DISCUSSION

Breeding season commencement and duration

Data from this study demonstrate at least a seven-month breeding season for the White-bellied Sea-Eagle in SA, i.e. commencing in May with stick carrying flights, courtship and nest repair activity, and extending into December with late fledging events possible in early January (Figure 2). With egg-laying occurring from late June to late August and peaking in mid-July in SA (Figure 2), this phase of the breeding season aligns with data from northern New South Wales (Debus 2008) and the Gippsland region of Victoria (Bilney and Emison 1983; Bluff and Bedford 2011; K. Hodge *in litt*.); but differs from tropical regions of Australia where egg-laying commences one to two months earlier (Lavery 1986; Corbett and Hertog 2011); and Tasmania where most egg-laying occurs in early September (Mooney and Holdsworth 1991; Threatened Species Section 2006; DPIPWE 2008).

Implications of seasonal disturbance

To many people large eagles are iconic symbols of wild places and their presence represents wilderness quality in a natural landscape (Threatened Species Section 2006). However, most eagle species (including the White-bellied Sea-Eagle) are sensitive to disturbance during the breeding season, particularly at the most critical period of courtship and nest building, when disturbance is likely to cause nest abandonment (Olsen 1998; Clunie 2004; Threatened Species Section 2006; U.S. Fish and Wildlife Service 2007). Absences from the nest increase the risk of predation of small nestlings and exposure to heat stress or hypothermia, and interrupted prey provisioning and feeding cycles can seriously affect nestling development and survival (Threatened Species Unit 2006; U.S. Fish and Wildlife Service 2007). With timeframes adjusted for South Australia (based on temporal data presented in this study), Table 1 sets out the typical stages of the *Haliaeetus* spp. breeding season cycle and the level of sensitivity associated with each (adapted from U.S. Fish and Wildlife Service 2007).

A long-term study of the White-bellied Sea-Eagle population on Kangaroo Island found a negative relationship between human activities and nest productivity (Dennis *et al*. 2011b). That study found that breeding pairs from disturbed territories were significantly less productive than those in more isolated locations, i.e. territories became active less often (65% of pairs produced eggs compared with 79%); fledged fewer young per year (0.36/year compared with 0.94); fledged young less often (every 2.9 years compared with 1.5); and experienced higher rates of nest failure (46% compared with 13%). When these findings are considered together with population declines and corresponding diminished range over mainland habitats (Dennis *et al*. 2011a), there are profound implications for long-term population stability in South Australia.

Habitat management

Many large eagle populations around the world are in decline (Newton 1979), including the White-bellied Sea-Eagle in Australia (Shephardson *et al*. 2005). Whereas habitat destruction represents the most significant threat (Clunie 2004), declines are related in no small part to anthropogenic encroachment, in all its forms, during critical phases of the breeding cycle. Studies to determine primary causes of nest failure among Bald Eagle *H. leucocephalus* and Spanish Imperial Eagle *Aquila adalberti* populations found that pedestrian incursions near nest sites provoked the strongest and most prolonged reaction (Grubb and King 1991; Gonzalez *et al*. 2006), particularly at remote sites, which suggests that some habituation occurs in territories nearer to human habitation (Gonzalez *et al.* 2006).

In recent decades, coastal tourism developments, residential development on coastal land sub-divisions, penetration into remote coastal areas by off-road vehicles and various forms of recreation (e.g. surfing, bushwalking, rock-climbing, fishing, hunting and intrusive photography), have each been implicated in the abandonment of White-bellied Sea-Eagle nest sites in South Australia (Dennis 2004; Dennis and Baxter 2006). To address similar conflicts elsewhere, prescriptive management plans have been developed to improve the refuge quality of eagle breeding habitat; for example, for the closely related Bald Eagle in North America (U.S. Fish and Wildlife Service 2007), and in Tasmania to protect White-bellied Sea-Eagle and Tasmanian Wedge-tailed Eagle *A. audax fleayi* breeding sites (Threatened Species Section 2006). Plan provisions include seasonal access restrictions (e.g. walking-trail closures during the breeding season) and the establishment of buffer zones to limit the impact of human activity and infrastructure development within a prescribed radius of nest sites (Richardson and Miller 1997; Camp *et al.* 1997; Romin and Muck 1999; Threatened Species Section 2006; U.S. Fish and Wildlife Service 2007; Thiollay 2007). Such habitat-management strategies, applied at critical phases of the breeding cycle, have been effective in increasing nest productivity for threatened eagle species (Anthony *et al.* 1995; Romin and Muck 1999; Gonzalez *et al.* 2006).

Because of the visual exposure of cliff nest sites (and associated strategic guard-roosts) over long distance in SA's typically open coastal habitats, and that activity or approach invariably occurs above nest level, spatial refuge dimensions of 2000-metre radius have been advocated (Dennis *et al.* 2011b). Although this distance is greater than prescribed for forested habitats in Tasmania (i.e. 500–1000 m), most nests there are at or above the tree canopy (Threatened Species Section 2006; Thurstans 2009), which provides visual screening and approach or disturbance occurs well below nest-level, which is less threatening to raptor species (Olsen 1998).

CONCLUSIONS

In recognition of demonstrated population declines in SA and low productivity levels associated with disturbance, and their innate propensity to abandon nesting early in the breeding season, the development of White-bellied Sea-Eagle habitat management prescriptions are advocated in South Australia to mitigate further decline. Such prescriptions need to consider temporal as well as spatial parameters and data presented in this study provide a basis for this to occur i.e. the risk of sea-eagle nest abandonment or egg-loss due to exposure, is greatest from mid-May to mid-September in SA (Table 1).

TABLE 1

Phases and timing of the White-bellied Sea-Eagle breeding season in South Australia and likely levels of sensitivity to disturbance for each (adapted from National Bald Eagle Management Guidelines (U.S. Fish and Wildlife Service 2007).

Activity phase	Time-frame	Sensitivity	Comments
Courtship and nest building and repair	May and June	Most sensitive period	Disturbance is likely to cause abandonment of nest and breeding attempts, particularly in newly established territories.
Egg-laying and early incubation	July	Very sensitive	Human activity of even limited duration within the core territory may cause nest desertion for the season.
Incubation and early nestling period	Late July to mid-Sept.	Very sensitive	Flushed adults leave eggs or small young vulnerable to predation and exposure (e.g. dehydration, hyperthermia or heat stress).
Nestling period, 4–8 wks	Mid-Sept. to mid-Oct.	Moderately sensitive	Risk of nest abandonment and vulnerability of young to prolonged exposure decreases; missed feedings may affect survival.
Advanced nestling period, >9 wks	Mid-Oct. to mid-Dec.	Moderately sensitive	Nestlings >9 weeks may flush from the nest prematurely if approached closely and subsequently perish.

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