Australian Field Ornithology 2012, **29**, 149–159

Nest-sites and foraging of the White-bellied Sea-Eagle *Haliaeetus leucogaster* on the subtropical eastern coast of Australia

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Summary. Nest-site characteristics (10 nests, of 9 pairs) and aerial foraging time-budgets of the White-bellied Sea-Eagle *Haliaeetus leucogaster* were studied on the Gold Coast and Tweed Coast (Queensland/NSW border region) of subtropical eastern Australia. White-bellied Sea-Eagle nests were situated high (>10 m) on lateral branch-forks in tall (>18 m), living, large-boled trees (>1.1 m diameter at breast height), mainly eucalypts in open forest, within ~1 km of waterbodies, and between 220 m and 1.1 km (mean 460 m) from human settlements. From the coastal plain to the subcoastal foothills up to 8 km inland, nests occurred at elevations up to 75 m above sea-level, but most were at ≤5 m asl; nests were on flat land or on slopes, the latter commonly with a southerly aspect. Two focal pairs of Sea-Eagles each spent ~15% of observation time (20 h per pair) in foraging-related searching and commuting flight, and <1% of aerial foraging time in attacking prey. Hunting success averaged 45% in 20 observed attacks on prey. There was no significant difference between the two pairs in aerial foraging time-budgets and hunting success.

Introduction

Until the 1990s only limited research had been conducted on the White-bellied Sea-Eagle *Haliaeetus leucogaster*, with respect to its nest-site characteristics and foraging behaviour, and then mostly in Victoria (Favaloro 1944; Emison & Bilney 1982; Marchant & Higgins 1993). Therefore, the present study sought to investigate these aspects on the subtropical eastern coast of Australia in 1998. Since that time, studies of the Sea-Eagle's nest-site selection and foraging have been conducted in New South Wales (NSW) (Debus 2008), Tasmania and Victoria (Thurstans 2009a,b; Wiersma & Richardson 2009; Hodge & Hodge 2011) and South Australia (Dennis *et al.* 2011a), with other studies focussing on human impact on the eagles and their nests (Spencer & Lynch 2005; Dennis *et al.* 2011b). Such research suggests that, in forested coastal environments, the Sea-Eagles generally nest in tall mature trees close to waterbodies, and that human proximity and habitat alteration are negative factors.

The aims of the present study were to (i) determine the distribution and density of White-bellied Sea-Eagle nests in the study area, (ii) measure and describe specific nest-site parameters of Sea-Eagles in a densely human-populated region, (iii) analyse foraging time-budgets and hunting success, and (iv) record some pertinent supplementary observations.

Study area and methods

The study area was the coast from Labrador, south-eastern Queensland (Qld) (27°56′S, 153°23′E), ~70 km south (linear distance) to Brunswick Heads on the far north coast of NSW (28°32′S, 153°31′E) (Figure 1). The coastline and coastal plain (including river valleys), up to 8 km inland to the subcoastal foothills and ranges, were surveyed for the presence of White-bellied Sea-Eagle nests. Vegetation around nest-sites ranged from closed or open forest to scattered trees in pasture. Sea-Eagle foraging habitats included artificial canals and lakes, floodplains, estuaries, beaches, inshore waters and offshore rock outcrops. The northern part of the study area (Gold Coast to the NSW border) was extensively modified by conurbation, particularly in areas beside water.

During the breeding season (July–September) in 1998, potential Sea-Eagle habitat was surveyed by WBO from elevated positions, using 10 × 50 binoculars, for direct prey-bearing flights by adult Sea-Eagles towards likely active nest-sites. These locations were plotted on topographic maps, and subsequently verified by foot survey to confirm nest-sites. The Gold Coast section was thoroughly surveyed, except for the Hinze Dam in the hinterland, where Sea-Eagles had also been seen. Not all pairs were found in the NSW section, where search effort was insufficient between the Tweed Valley and Brunswick Heads.

Nest-site parameters measured or described, for 10 nests of nine pairs, were:

Nesting habitat (vegetation type),
Nest-tree species,
Nest-tree height (m),
Nest-tree health status (live, crown dieback or dead),
Nest-tree diameter at breast height (dbh, m),
Height of nest above ground (m),
Branch order of nest-fork (lateral branch versus bole fork),
Nest-tree elevation above sea-level (m, asl),
Aspect (cardinal compass direction that slope faces),
Distance to a major waterbody (m), and
Proximity to human settlement (m).

Nest-tree parameters were determined by tape-measure or telescopic measuring rod, and other parameters were determined from aerial photographs and topographic maps.

Two of the 10 active Sea-Eagle territories were the subject of focal observations of foraging behaviour by WBO: Pair A at Merrimac (Qld; 28°03′S, 153°22′E) and Pair B at Hastings Point (NSW; 28°21′S, 153°33′E). Both territories offered accessible, unobstructed viewing points over the eagles' nest-sites and home-ranges. Twenty hours of observation, each consisting of 10 × 2-h sessions, were allocated to each pair; sessions were spread across different times of day for each pair, so that observations sampled various times of day within pairs and were comparable between pairs. Commencement and termination of aerial foraging bouts were equated with departure from, and arrival at, major perching sites, and only those flights clearly associated with foraging were included (e.g. flight bouts strictly involving nest-material collection and/or territorial display were excluded). It is recognised that some foraging may be by perch-hunting (still-hunting), and such 'passive' hunting to locate prey may be difficult to distinguish from simply perching (e.g. resting). However, the eagles' major perching sites were 380–420 m from water and were associated with nest-trees, rather than located within 100 m of water as is typical for still-hunting *Haliaeetus* eagles (Watts 1999). Only aerial foraging behaviour is considered here.

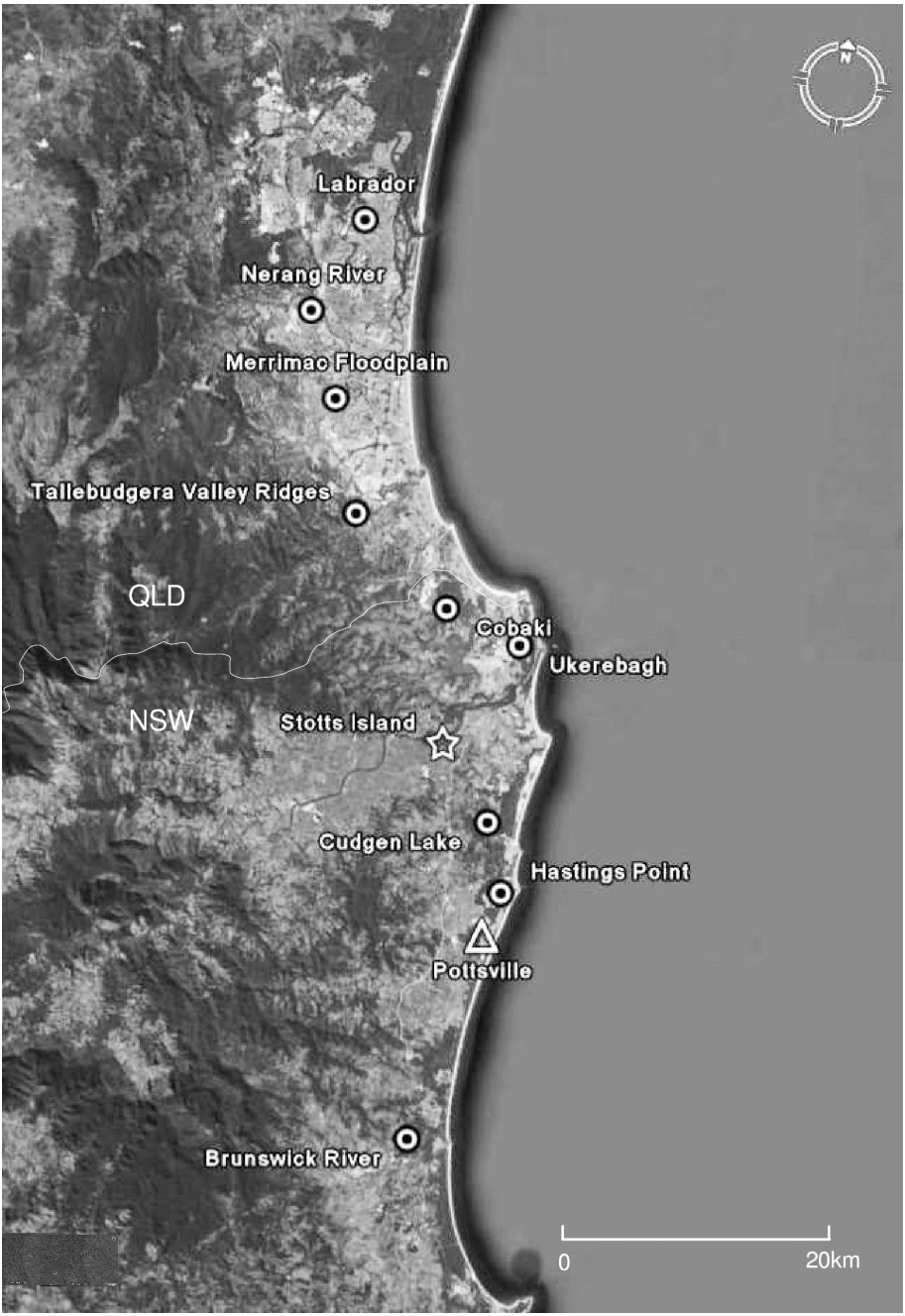

Figure 1. Location of White-bellied Sea-Eagle pairs and nests in the study area: circle = confirmed active nest; triangle = nest confirmed but not watched; and star = probable nest of additional pair. Source of image: Google Earth

All observed aerial foraging bouts were timed by digital stopwatch, and separated into travel time (time spent on the wing searching for and locating prey, plus return flight time) versus attack time (time spent pursuing and/or grappling prey). Foraging success (capture of prey items, including when procured by piracy and scavenging) was calculated as a proportion of total capture manoeuvres (number of pursuits and/or attacks). Differences between pairs, in travel time versus attack time and in foraging success, were assessed by chi-squared analysis.

Results

Eagle population

Eleven White-bellied Sea-Eagle pairs were confirmed in the study area, with active nests of 10 pairs located (Figure 1). Adult behaviour (displays and calling) strongly suggested the likelihood of two other pairs with nests, i.e. there were probably two additional nests in NSW and therefore 13 pairs in the study area.

Thirteen Sea-Eagle pairs were found over ~70 km of coastal plain (~500 km^2); however, this may be an underestimate for the NSW section of the study area. In the intensively surveyed Gold Coast section, there were six pairs in 35 km of coastal plain, with regular spacing of 6–9.8 km (mean 7.9 km, n = 5) between neighbouring nests. Nearest-neighbour distance was not determined in the NSW sector, but two nests were 3.8 km apart, with others 5.5 km and 6.8 km apart. Two other probable nest-sites were <6 km from known nest-sites.

Although the Gold Coast habitats were likely to be highly disturbed, canal estates and major waterways were readily accessible from the eagles' nest-sites, and apparently provided suitable foraging opportunities. One Gold Coast nest-site (Labrador) has since been deserted following the encroachment of urbanisation, and is now a shopping centre (Harbour Town).

An active nest just south of the study area, near Tyagarah ~10 km south of Brunswick Heads, in 2010, was attended by a pair of Sea-Eagles and an extra adult female (T. O'Keefe pers. comm., from almost daily observations throughout the breeding cycle). When the incubating female started to spend time off the nest, the other female tended the nest, removing food remains and repositioning sticks in the presence of the breeding pair. This behaviour lasted until around the third week post-hatching, but the extra female was not seen to feed the chicks. These birds were filmed by professional film-maker David Warth, of Byron Bay (NSW).

Nest-sites

Most nest-trees used by Sea-Eagles (n = 10) were in open forest formations (60%, n = 6), with one (10%) in closed forest and three (30%) in remnant trees in pasture (Table 1). Eight nests (80%) were in eucalypts (five in Blackbutt *Eucalyptus pilularis*, three in Forest Red Gum *E. tereticornis*), with the remainder in Brush Box *Lophostemon confertus* and fig *Ficus* sp. Nest-trees were 18–28 m tall (mean 23.2 m, standard deviation 3.4), with a dbh of 1.1–2.1 m (mean 1.5 m, s.d. 0.3); all were alive, although six had crown dieback (dead tops) which produced prominent 'stags'.

Table 1. Vegetation types associated with 10 coastal White-bellied Sea-Eagle nest-sites near the NSW–Qld border, 1998.

Vegetation type	*No. nests*	*%*
Closed forest	1	10
Grassy open forest	2	20
Layered open forest	3	30
Shrubby open forest	1	10
Remnant pasture tree	3	30
Total	10	100

Nests were placed at 10–23 m above ground (mean 16.9 m, s.d. 3.7). All were placed in lateral (i.e. second-order) branch-forks, typically having multiple branches providing radial support, rather than in bole (first-order) forks that provide only bilateral support. Nest-sites occurred at a range of elevations (2–75 m asl, mean 19 m, s.d. 26), although most (60%) were found at ≤5 m asl (Table 2). Some nest-trees (40%) were on flat land. Of those on slopes, nests with a southerly aspect predominated (30% of total sites: Table 2), although sample size was small (three south-facing, versus one each facing north, east and west).

Table 2. Elevation (m asl) and slope aspect (cardinal compass bearing) of 10 coastal White-bellied Sea-Eagle nest-sites near the NSW–Qld border, 1998.

Parameter	*No. nests*	*%*
Elevation class (m):		
≤5	6	60
6–10	1	10
11–20	0	0
21–30	0	0
31–100	3	30
Total	10	100
Slope aspect:		
Nil (flat)	4	40
N	1	10
S	3	30
E	1	10
W	1	10
Total	10	100

Table 3. Travel time versus attack time during aerial foraging bouts by members of two pairs of White-bellied Sea-Eagles, NSW–Qld border, 1998 (20 h of observation per pair).

Pair	*Travel time (h)*	*Attack time (min.)*	*Total (h)*
A	3.20	1.0	3.22
B	2.62	0.9	2.63
Total	5.82	1.9	5.85
%	99.4	0.6	100

Nests were situated between 12 m and 1.1 km from a major waterbody (mean 380 m, s.d. 0.3), and between 220 m and 1.1 km from human settlement (mean 460 m, s.d. 0.3). Thus, all nests were near/overlooking or within ~1 km of water, and were located a minimum of 220 m from existing human habitation. However, one nest located 12 m from a major river was subject to the daily presence of fishers travelling past in motor boats.

Foraging

Prey items taken at the Merrimac site were fish, including eels *Anguilla* sp., Eastern Great Egret *Ardea modesta* and Straw-necked Ibis *Threskiornis spinicollis*. Prey items taken at the Hastings Point site included fish, pirated from Eastern Ospreys *Pandion cristatus* and Whistling Kites *Haliastur sphenurus* and taken from the sea within 300 m of the shore.

Members of the two focal Sea-Eagle pairs spent 13% and 16% of respective observation time (20 h per territory) in foraging-related flight and return travel. (Perch-hunting, i.e. stationary scanning for prey, is not considered or quantified here, but was observed as a precursor to a piracy attack on an Osprey.) Only 0.5–0.6% of total foraging-related flight and commuting time was spent in attacking prey, with no significant difference between the two pairs in this proportion of their respective foraging time-budgets (Table 3; $\chi^2_1 = 0.51$, $P > 0.05$).

Table 4. Hunting success (number of successes vs number of failures) during aerial foraging bouts by members of two pairs of White-bellied Sea-Eagles, NSW–Qld border, 1998 (20 h of observation per pair).

Pair	*No. successes*	*No. failures*	*Total attacks*
A	6	5	11
B	3	6	9
Total	9	11	20
%	45	55	100

Figure 2. Juvenile White-bellied Sea-Eagle. Photo: Ian Ladyman

Hunting success, in terms of number of food items procured per attack, was 55% and 33% in territories A and B, respectively, or 45% overall from the pooled sample of 20 observed attempts (Table 4), with no significant difference in foraging success between the two territories ($\chi^2_1 = 0.9$, $P > 0.05$). That is, almost half of the observed attempts (0.8:1) resulted in a capture.

Discussion

Eagle population

Inter-nest distances of the White-bellied Sea-Eagle on the Gold Coast were lower than recorded elsewhere in coastal NSW and eastern Queensland (compare Marchant & Higgins 1993; Debus 2008), and may be explained by the highly urbanised environment of the Gold Coast. Furthermore, the nesting habitat of one Gold Coast pair has since been lost to encroaching urbanisation. No clear conclusions could be drawn about nearest-neighbour distances for the Tweed Coast, but preliminary data suggest that Sea-Eagle nests are closer together there than on the Gold Coast. However, given the predicted doubling of the human population on the NSW North Coast over the next two decades (D. Brunckhorst unpubl. data), the Tweed Coast is likely to follow the trend of the Gold Coast.

Apparently polygamous trios are occasionally recorded in other, normally monogamous raptors, including some sea- or fish-eagles and, mostly notably, in the critically endangered Madagascan Fish-Eagle *Haliaeetus vociferoides* where the behaviour is frequent (e.g. Tingay *et al.* 2002; Tingay 2010). We speculate that the breeding trio at Tyagarah may be a symptom of reduced breeding density (through habitat loss) and/or reduced breeding success, resulting in fewer mates or breeding opportunities, for the White-bellied Sea-Eagle on the Gold Coast–Tweed Coast. Alternatively, the trio may reflect a local or regional shortage of suitable breeding territories for the number of mature eagles present.

Nest-sites

White-bellied Sea-Eagles on the subtropical eastern coast of Australia appear to have specific nest-site requirements: large, mature or old living trees (usually eucalypts) with massive boles, usually in open forest, within ~1 km of a waterbody, and at least 220 m from human settlement. The two favoured eucalypt species, at least in forest, have trunks forming more than half the total height of the tree (Boland *et al.* 1992). Live trees provide partial shade for nestlings (e.g. Newton 1979; Thurstans 2009a), and nests in dead trees may be readily blown down in the cyclonic subtropics. Elsewhere, dead trees are used rarely, are probably alive when first used, and may be abandoned soon after the tree dies (e.g. Marchant & Higgins 1993; Debus 2008).

Eucalypts may be the most commonly available large trees, but may also provide the necessary branch conformation to support the large nest of a Sea-Eagle. Dead-topped or emergent eucalypts also give prominent lookout perches (e.g. Debus 2008; Thurstans 2009a). Nests in lateral (second-order) forks may provide greater structural support than in bole (first-order) forks, but their greater height above ground may also give greater security from terrestrial predators.

In the parameters assessed, the White-bellied Sea-Eagle nest-sites in this study closely resemble those in other forested coastal environments in south-eastern Australia (e.g. Emison & Bilney 1982; Marchant & Higgins 1993; Debus 2008; Thurstans 2009a; Hodge & Hodge 2011). For instance, tree height, height of nest above the ground, and prominent lookout posts enhance nest security, vigilance for nest-predators, competitors and prey, and territorial advertisement (Newton 1979; Olsen 1995). In the Sea-Eagle and other large eagles in Australia, preferred topographic position, aspect and location in relation to surrounding tree-canopy cover all confer protective benefits for nests and their contents, and location within forest rather than in remnant trees in cleared areas enhances breeding success (Emison & Bilney 1982; Thurstans 2009a; Foster & Wallis 2010). Location near foraging grounds (i.e. waterbodies for the Sea-Eagle's primarily aquatic prey) probably relates to the energetic efficiency of transporting large prey to nestlings (e.g. Newton 1979; Wiersma & Richardson 2009). Location away from human settlements would minimise the human disturbance to which this species is sensitive (e.g. Thurstans 2009a,b; Dennis *et al.* 2011b), although some habituation to fishing-boat traffic was evident. White-bellied Sea-Eagles are much less nervous or disturbed by human activity on water than on land (N. Mooney per S. Thurstans pers. comm.).

It is noted here that one claimed 'Sea-Eagle' nest on a power pylon on the Gold Coast, relocated to a purpose-built platform at great expense (Stolz 2007), was investigated following the present study, and found to be that of an Osprey. This incident illustrates (i) the ongoing confusion of these two species by the authorities, wildlife 'experts' (?) and 'consultants', media and the public, and (ii) the consequent lack of authentic records of White-bellied Sea-Eagles voluntarily building nests on artificial structures.

Foraging

Prey items were typical for this species in coastal areas (e.g. Marchant & Higgins 1993; Hodge & Hodge 2011). The nesting adult Sea-Eagles in this study spent a small proportion (<20%) of observation time in aerial foraging and related travel, and a minute proportion (<1%) of foraging time in attacking prey. Both focal pairs were similar in these respects, although the sample size was small. Active attack flight is vigorous and energy-demanding, whereas searching and commuting flight uses soaring and gliding (e.g. Marchant & Higgins 1993; Debus 2008; Wiersma & Richardson 2009). Other similar-sized, tropical or subtropical fish-eagles similarly spend little of the day actively hunting (African Fish-Eagle *Haliaeetus vocifer*: Brown 1980).

The two focal pairs of White-bellied Sea-Eagles in this study had similar foraging success and, although the sample size was small, this finding may be typical for the species in the region. Their average strike success rate of 45% was similar to that of 39% observed by Debus (2008) on an inland lake, where strikes at surface fish in still water were particularly successful. White-bellied Sea-Eagles may have higher hunting success rates than some other Australian raptors that actively pursue vertebrates, e.g. Brown Goshawk *Accipiter fasciatus* 37%, Swamp Harrier *Circus approximans* 29% and Peregrine Falcon *Falco peregrinus* 31% (Olsen 1995). However, breeding adult Wedge-tailed Eagles *Aquila audax* can have high hunting success (80%: Debus *et al.* 2007).

Conclusions

The White-bellied Sea-Eagles in the study area appeared to site their nests so as to deter nest-predators, maximise shelter, vigilance and advertisement (to conspecifics), maximise access to hunting grounds, and minimise human disturbance, as in other studies. A clear preference for topographic elevation and aspect, over those categories locally available, was not evident but is likely, and requires further study with larger sample sizes. Similarly, the Sea-Eagles also appeared to maximise energy efficiency in their foraging and attack time-budgets, and their hunting success, but further study of these aspects is also required with larger sample sizes. Such studies might usefully investigate Sea-Eagle nesting density, breeding success, and foraging success and energetics, in relation to habitat availability (nest-sites and hunting grounds), prey availability and human impacts. Research is needed in the present study area, where Gold Coast-style development threatens to engulf the adjoining Tweed Coast in NSW, and thus potentially threaten a federally listed 'migratory' (and 'sentinel') species that also requires an updated assessment of its conservation status in NSW (see Debus 2008). For instance, the 13+ pairs in ~70 km of the heavily urbanised Gold Coast–

Tweed Coast, with only six pairs (now five?) in 35 km of the Gold Coast, compare rather unfavourably with ~20 pairs in ~80 km of the less urbanised Clarence Coast (NSW) farther south (G. Clancy in Debus 2008). The polygamous trio may also be an early-warning sign of a local White-bellied Sea-Eagle population in decline, or short of suitable breeding habitat.

Acknowledgements

This study was an undergraduate research project by WBO in zoology at the University of New England, Armidale (NSW), taught and supervised by Prof. Hugh Ford. Thanks go also to the late Alex Griffiths (founder, Currumbin Bird Sanctuary) and the late Basil Smith for reporting Sea-Eagle foraging and perching sites on the lower Gold Coast, and Troy O'Keefe for permission to quote his record of the polygamous trio. We acknowledge Prof. David Brunckhorst (Institute for Rural Futures, UNE) for his population prediction. SD gratefully acknowledges the facilities of the Division of Zoology, UNE. We thank Shaun Thurstans, Jason Wiersma and an anonymous reviewer for helpful comments on a draft.

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Received 20 October 2011 ■