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Response of White-bellied Sea-Eagles *Haliaeetus leucogaster* to encroaching human activities at nest sites

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Nest sites of the White-bellied Sea-Eagle *Haliaeetus leucogaster* are under increasing pressure from encroaching development and other human activities in coastal south-eastern Australia. Nests in the path of development have sometimes been destroyed or displaced, or become too disturbed for continued successful breeding. This paper reviews eight such cases, six for which mitigation measures (artificial platform, exclusion or environmental protection zones, forced rebuilding at safer sites) were attempted, successfully in three of these (i.e. young fledged) after management actions:

(1) Relocation of the intact nest to a platform among other trees nearby (successful in the short term (6 years), ultimately abandoned);

(2) Removal of a pair's nests in a highway upgrade zone, to encourage rebuilding in safer forest sites nearby (initially successful);

(3) Exclusion zone (50 m and 130 m radius) buffering a long-term nest from a new housing estate on three sides (successful in the short term, 2 years);

(4) E3 zoning ('Environmental Management') of a bushland remnant enclosing a formerly productive eagles' nest adjoining a new housing estate (nest unsuccessful then abandoned after development proceeded);

(5) Site management of a long-term nest in a recreation reserve 30 metres from a new housing estate (inconclusive, as the eagles left the site before clearing commenced);

(6) Deactivation of an established nest in a pipeline easement, to encourage rebuilding in safer forest sites nearby (use and outcome of a possible alternative nest not determined by the proponent).

Overall, buffer zones (50–130 m around active nests) had mixed success, and the more highly and frequently disturbed nests had low breeding productivity or were abandoned. With rapid expansion of urbanisation likely to continue in coastal northern New South Wales, this region may become a population sink for the White-bellied Sea-Eagle. Therefore, given its small population (~800 pairs in NSW) and the potential for an estimated 10 percent decline in abundance in three generations (this study), it is recommended that the Sea-Eagle be considered for listing as *vulnerable* in NSW.

INTRODUCTION

Various studies have shown the White-bellied Sea-Eagle *Haliaeetus leucogaster* to be adversely affected by human disturbance, particularly to breeding habitat and nest sites during the eagle's breeding season (e.g. Emison and Bilney 1982; Bilney and Emison 1983; Marchant and Higgins 1993; Stokes 1996; Spencer and Lynch 2005; Debus 2008; Thurstans 2009a,b; Corbett and Hertog 2011; Dennis *et al.* 2011a,b, 2012). In heavily human-populated coastal regions of south-eastern Australia, pressure on the species now arises mainly from encroaching urbanisation and associated human infrastructure, recreational activities, chemical pollution, and entanglement in fishing gear (e.g. Shephard *et al.* 2005; Spencer and Lynch 2005; Manning *et al.* 2008; Steele-Collins 2008; Thurstans 2009b; Bluff and Bedford 2011; Hodge and Hodge 2011; Anon. 2012; O'Donnell and Debus 2012; Olsen *et al.* 2013). However, clandestine (illegal) persecution also persists, including in response to protection of nests from development and alleged predation on poultry (Anon. 2009; Wiersma 2010; Mooney 2013a).

Attempts to mitigate human disturbance to active Sea-Eagle nests have sometimes included the proposed relocation of an established nest to an artificial platform. One documented instance was successful in the short term, as the eagles continued to breed successfully in the relocated nest for several years (see Wieneke 2005; Ezzy 2008). Another case involved installing a decoy nest structure, to encourage a pair to shift away from a windfarm development (a failed strategy; Mooney 2013b). There is only one known record of White-bellied Sea-Eagles voluntarily building on an artificial structure: a very large nest occupied for about 10 years from 1995, on a telecommunications tower at Kalbarri on the arid Western Australian coast (J. Shephard pers. comm.). Another claim concerned misidentified Eastern Ospreys *Pandion cristatus* nesting atop a high-voltage power pylon on the Gold Coast in Queensland (O'Donnell and Debus 2012). White-bellied Sea-Eagles almost invariably select natural sites such as cliffs or trees, the latter usually alive, at least when the nest was first built (e.g. Marchant and Higgins 1993; Debus 2008; Thurstans 2009a; O'Donnell and Debus 2012).

There are few empirical data on the behavioural response of White-bellied Sea-Eagles to human disturbance, and particularly on attempts to mitigate such disturbance. This study discusses several case histories, and their outcomes, of active Sea-Eagle nests affected by development proposals where attempts were made to mitigate the effects of disturbance, and includes an update on the relocated nest described by Ezzy (2008).

STUDY AREAS AND METHODS

The following case histories concern six White-bellied Sea-Eagle nest locations on the subtropical east coast of Australia:

(1) The Bunnings warehouse development at Townsville, Queensland (19°16'S, 146°49'E) (see Ezzy 2008);

(2) The Pacific Highway realignment between Coffs Harbour (30°18'S, 153°08'E) and Woolgoolga (30°07'S, 153°11'E), New South Wales;

(3) Vegetation clearance for a housing development at Brendale near Strathpine (27°19'S, 153°00'E) on the northern outskirts of Brisbane, Queensland;

(4) Recent (post-2006) encroachment of urban development at Pottsville (28°24'S, 153°34'E) on the Tweed Coast, New South Wales;

(5) Vegetation clearance and construction of a new housing estate at Noosaville (26°24'S, 153°04'E) on the Sunshine Coast, Queensland (JWA 2004);

(6) Vegetation clearance for a gas pipeline easement on Curtis Island near Gladstone (23°51'S, 151°16'E) in coastal south-east Queensland.

Two other cases of Sea-Eagle nests in the path of development proposals are described:

(7) Bundabah, near Karuah (32°39'S, 151°58'E), on Port Stephens (NSW);

(8) Pinkerton Forest, Mount Cottrell near Melton (37°41'S, 144°35'E), southern Victoria.

The 'EagleCAM' site at Sydney Olympic Park is also considered, as an artificial platform was contemplated after the original nest collapsed (references in Appendix 1).

At the Townsville and Strathpine territories, nest sites were monitored regularly before and after development and mitigation measures, by GB and other BirdLife Townsville members (Townsville, 2002–2013) and by BN (Strathpine, 2009–2013), respectively, to ascertain annual occupation and fledging success.

At Coffs Harbour, the various nest sites were monitored by SD and/or DO in May 2010, October 2010, April–November 2011 (mostly by DO), and May–October 2012 (by DO, fortnightly from 30 May to 26 July). Surveys were conducted in consultation with the development proponents, either before or after scheduled stages in the development were conducted (e.g. forest clearing, excavation, blasting, nest-site manipulation). The proponent's arborists inspected the nests for eggs before action was taken to remove those nests. In 2011 the nest site was monitored regularly from early June to late August (by DO) during clearing activities and blasting within the quarry area, and in July–August 2013 for signs of the eagles breeding; the nest was not approached or climbed until after it had failed (see below).

In the Pottsville case, an occupied nest was first identified in 1998 (O'Donnell and Debus 2012), and since 2010 a new nest in the same territory was monitored regularly by the Tweed Bird Observers (Tweed Osprey Group) as a new housing development encroached on the bushland territory. Information was provided to SD by F. Hill (pers. comm.).

At Noosaville, the situation was managed by the development proponent's environmental consultants, who formulated mitigation strategies for the nest (JWA 2004) and provided relevant information to SD. Similarly for Curtis Island, information was relayed by ecological consultants and other personnel involved in the Queensland Gas Co pipeline development.

In all cases monitored by the authors and their associates or informants (e.g. BirdLife Townsville, Tweed Osprey Group), observation of occupied or active nests was conducted remotely, from the ground using binoculars and/or telescope, at discreet distances considered unlikely to cause disturbance or desertion, and nest sites were not climbed. Inspections by development proponents or their agents were more intrusive at nests scheduled to be sacrificed, by climbing to confirm that there were no eggs present before the nest was removed.

Terminology follows prior related studies on Sea-Eagles (e.g. Dennis *et al.* 2011a, 2012), i.e. 'occupied' means adult(s) attending a nest; 'active nest' means eggs or chicks observed or inferred; 'guard-roosts' mean prominent perches around the nest (often emergent, dead or dead-topped trees). It is assumed that the adult eagles were the same individuals post-disturbance, although it is not known whether, for instance, the pair post-disturbance included a new bird having no prior history at the site.

Disturbance was rated according to the level of human activity: High (nest climbed, nest removed and site cleared); Medium (nest not climbed, human activity around base of nest tree/pole, clearing and/or urbanisation within 100 m); Low (discreet observation only, from outside eagles' flush distance). The eagles' breeding productivity was rated as normal or below normal for undisturbed populations in southern Australia (from values in Marchant and Higgins 1993, Debus 2008 and Dennis *et al.* 2011b, i.e. a threshold of 0.8 young/territory/year).

RESULTS AND DISCUSSION

Results are summarised in Tables 1 and 2, in terms of the eagles' response to mitigation strategies and the effect of varying disturbance levels on their productivity. Overall, buffer zones of 50–130 metres radius around active nests had mixed success; the more highly and frequently disturbed nests had low breeding productivity, and were ultimately abandoned.

Townsville

The history of this case is given elsewhere (Anon. 2003; Wieneke 2005; Ezzy 2008). The eagles' long-established nest in a large eucalypt was in an area to be cleared, so between the 2002 and 2003 breeding seasons the nest structure was moved intact to a cradle atop a 15-metre pole 100 metres away, next to

Table 1

Summary of mitigation strategies for White-bellied Sea-Eagle nests subject to development activities, and their outcomes. Details of sites, development activities and strategies in text; forced move = occupied nest removed or deactivated.

Site	Strategy	Outcome
Townsville (Qld)	Forced move to pole and platform	Successful (B/1 or B/2 fledged annually) for 6 years, then nest abandoned.
Coffs Harbour (NSW)	Forced moves to natural sites in forest	Year 1 successful: B/2 fledged from new nest. Year 2 unsuccessful: B/1 hatched, nest failed. Year 3 unsuccessful: nest not used, new nest or fledglings not found.
N Brisbane (Qld)	Buffer zones (50 m on 2 sides; 130 m on 1 side)	Successful: B/1 fledged in next 2 years.
Tweed Coast (NSW)	Council zoning (E3, 'Environmental Management')	Initially successful: B/1 fledged in year 1. Thereafter unsuccessful: laid but failed in year 2, nest abandoned in years 3 and 4.
Sunshine Coast (Qld)	Management plan, buffer zones (30 m; 100 m in breeding season)	Untested: eagles abandoned site before development.
Curtis Is. (Qld)	Forced move	Use of and success in alternative nest not determined by proponent.

Table 2

Summary of disturbance levels at White-bellied Sea-Eagle nests, and eagles' and breeding performance (where known). For disturbance levels and normality of breeding productivity, see text. N/a = not applicable.

Site and nest	Disturbance	Breeding productivity
Townsville:		
Nest 1 (original)	High	N/a (nest removed before laying)
Nest 2 (pole and platform)	Medium	Normal for 6 years, then abandoned
Nest 3 (near-urban)	Medium	Normal for 2 years (uncertain if same individual eagles)
Coffs Harbour:		
Nest 1 (original)	High	N/a (nest removed before laying)
Nest 2 (in forest)	Low	Normal
Nest 3 (on forest edge), years 1–2	Medium (increasing)	Below normal, nest ultimately abandoned
N Brisbane (near-urban)	Medium	Normal for 2 years
Tweed Coast (urbanising)	Medium (increasing)	Below normal, nest ultimately abandoned

a stand of tall eucalypts. The relocated nest was overhung by a tree crown, on the edge of the Bunnings carpark (Figure 1), but was not surrounded by a disturbance-free exclusion zone. The eagles tolerated routine human activity in the carpark (including the closest part as a loading-bay storage area), and successfully reared one or two young annually in the relocated nest from 2003 to 2008 inclusive. Early in 2009 there appeared to be a challenge for the nest, with three adult eagles calling at the site, but the eagles moved away and no nesting activity took place. During this time, Bunnings staff used the ground below the nest as a smoking area, but this practice was then moved elsewhere, away from the nest site.

In 2009–10, a Sea-Eagle pair was often seen along the Ross River and in the general area, but made no attempt to rebuild the Bunnings nest. The adjoining trees meanwhile had grown, and the nest had become more enclosed by foliage, possibly making the site unsuitable for the eagles. Around June 2010, Bunnings staff reported Sea-Eagle activity around the nest pole, so lopping of the encroaching foliage was delayed until after the breeding season. However, it appeared that the eagles added no new material to the platform nest in 2010.

Figure 1. *White-bellied Sea-Eagles' nest on artificial pole and platform, Bunnings carpark, Townsville, (Qld.), June 2008.*

Photo: George Baker

By May 2011, Bunnings had not conducted the requested tree-lopping or relocation of the storage area. It appeared that the nest site was no longer attractive to the eagles, owing to the overhanging branches and the increased noise from the storage works below, and the nest was claimed by a pair of Black Kites *Milvus migrans* which defended it against other raptors.

A pair of Sea-Eagles had by then started to build a new nest on the Ross River four kilometres away, but it was uncertain whether these were from the Bunnings site. The new nest was partly built in 2010, in a tall tree amid private suburban gardens 500 metres off the river (Figure 2). The eagles resumed building in 2011, until Cyclone Yasi dislodged much of the nest in February. The cyclone also wrecked many of the adjacent trees, including a large tree that toppled into the nest tree. The eagles returned and repaired the nest, which was within 50 metres of a house and in plain view (Figure 2). Council tree-loppers then removed branches from the toppled tree and tidied up the nest tree, but the eagles returned to the nest, fledging one eaglet in late October. Meanwhile, there was no Sea-Eagle activity at the Bunnings site. Thus, the relocated nest was successful for six consecutive years (2003–2008), after which it was abandoned. This length of occupation is lower than the eagle's normal nest-site fidelity, as nests can be occupied for decades (Marchant and Higgins 1993). For example, most nests in one study were occupied for at least 14 years, although these were cliff rather than tree nests (Dennis *et al.* 2011b). Conversely, nearly one-third of 76 nests were lost or abandoned within 20 years, with one-third of that turnover related to human disturbance (Thurstans 2009b).

In 2012 the eagles re-used the Ross River nest, being first seen rebuilding it early in April. Two chicks hatched, but only one fledged (in October). The local people have assumed some 'ownership' of these eagles and their nest. In 2013, two young fledged in October (G. Zaverdinos pers. comm.).

Coffs Harbour

In April 2010 an occupied Sea-Eagle nest was found in forest within 10 metres of planned clearance for the Pacific Highway realignment, leaving a 15-metre-wide strip of forest bordering cleared farmland. The eagles appeared not to have started renovating or lining the nest for the 2010 breeding season. As the schedule of the major highway project could not be delayed, the proponent considered relocating the nest or constructing a platform (as for Ospreys) to attract the eagles away from the disturbance zone. However, in light of the Bunnings experience and no precedent for the species' acceptance of artificial platforms for new nests, this strategy was deemed unnecessary, as there was extensive adjoining forest providing alternative nest sites.

As clearing limits were adjacent to the nest tree and the eagles' nearby guard-roosts, and major earthworks were scheduled to coincide with the breeding season, the eagles were encouraged to nest away from the disturbance by removing the nest and lopping the support branch. This was done in May, before the eagles laid eggs, and was successful: the eagles built a new nest 170 metres away, in adjoining State Forest, and subsequently fledged two young in October 2010. Meanwhile, earthworks near the original nest had been completed, and would have caused that nest to fail had it been used in 2010, and rendered that site unusable in the future, owing to its exposure and proximity to chronic disturbance.

Figure 2. *White-bellied Sea-Eagles' nest near Ross River, Townsville, (Qld.), May 2011 (note house roof in foreground).*
Photo: George Baker

The new nest was still in the project area, on a proposed quarry site for highway material. As quarry works (clearing, excavation and blasting) were scheduled to coincide with the 2011 breeding season, the same strategy was adopted, i.e. the nest was removed in April before eggs were laid, because the nest was likely to fail in 2011 and had no future beyond that. Again the eagles built a new nest, only 20 metres away and still within the quarry footprint, so it too was removed before eggs were laid.

At the end of May, the eagles had built a third nest, this time in State Forest 80 metres away from the quarry boundary and within a conservation zone, and subsequently laid egg(s). Monitoring, and a 100-metre disturbance-free buffer from the quarry (the standard exclusion zone for active nests of threatened raptors and owls in NSW), were recommended and implemented.

The eagles appeared not to be disturbed by clearing activities or earthworks in the quarry area, with one or both adults remaining near the nest. During a trial blast, they were at the nest and took flight at the blast, though both returned to the nest within five minutes. At that stage (25 August) there was at least one chick, seen to be fed by an adult. On the day before the main blast (11 September), one adult was briefly near the nest during 2.5 hours of observation, and there were no signs of nest activity or nestlings. In the preceding week of warm weather there had been much goanna (Lace Monitor *Varanus varius*) activity in the general area, with goanna scratches on the nest-tree trunk. Neither adult eagle was observed near the nest on the day of the main blast (12 September, from 1 hour before until 45 minutes after the blast). During eight hours of subsequent early morning, midday and dusk watches, neither adult was seen at or near the nest, and it was therefore assumed that the nest had failed. The proponent's climber inspected the nest on 13 October, confirming nest failure (no eggs or nestlings). The proponent therefore immediately commenced the final clearing (within the 100-m buffer) needed in order to use the quarry area for obtaining/storing overburden material.

Movement of heavy machinery occurred constantly in the area thereafter, and it is likely that this activity contributed to the eagles not using that nest in 2012. During fortnightly observations from the end of May to late July 2012 (at least 1 hr in early morning or late afternoon), there was no activity or evidence of use. The

Figure 3. *Fledgling White-bellied Sea-Eagle, Strathpine site (Qld.), October 2012.*

Photo: Ben Nottidge

eagles were nearby on some occasions (i.e. perched on a dead limb of a large tree several hundred metres away), but they were not observed near the nest, which appeared in poor condition with no new material evident. Despite several searching traverses in adjacent forest, in the area of observed eagle activity in August/September, no new nest was detected during the 2012 breeding season. In July 2013 there was no sign of Sea-Eagle breeding activity at the 2011 nest, although the adult eagles were present 200 metres away. Overall, this repeatedly disturbed and harried pair has had below-normal breeding productivity (two young in three pair-years, or 0.67 young/year).

Strathpine

In May 2009, an occupied Sea-Eagle nest was found in an area scheduled to be developed as a housing estate (bushland bordering a water body). The eagles bred in 2009–11 inclusive, fledging young each year in October, although in 2011 the fledgling was found dead 150 metres from the nest. The adjoining area has been a quarry since the 1960s, so the eagles were probably habituated to some level of routine disturbance. The subdivision involved extensive clearing of native forest on three sides around the nest tree (north-west to south-east), and the proponent had agreed to a minimum 50-metre buffer around the tree on two sides, with a 130-metre buffer remaining on the third side, and forest extending to the eagles' foraging grounds. Clearing commenced in November 2011, i.e. after the 2011 breeding season, and was completed by March 2012.

In 2012 and 2013 a pair bred at the 2011 nest site again, despite the significant loss of surrounding forest habitat, and successfully fledged one eaglet (in early October) in both years (Figure 3).

Tweed Coast

In 2010 the eagles' current nest was found in remnant forest (within 50 m of a forested section of road) near the cleared southernmost section of Black Rocks Estate (South Pottsville), which then had new roads but no houses. The roadway between the housing development and a new sportsfield (~250 m to the west) had been cleared in or before 2006, and was accessible to 4WD vehicles and dirt bikes via bush tracks. The road was blocked by a high fence during 2009 and much of 2010, thus restricting disturbance to the nest early in the season in 2010, but was unblocked when the eagle chick was still downy. Preparation for the development had already begun by 1998, involving drainage and construction of a small lake (~500 m from the eagles' nest). Filling and further preparation of the housing site and sportsfield accelerated in 2006, accompanied by many truck movements and earth-moving machinery. Building of houses began around mid 2011. The nest was between the sportsfield (<100 m to the west) and the edge of the housing estate (~200 m to the east). The eagles raised one fledgling in 2010; laid egg(s) in 2011 (incubating June–July) but failed (as revealed by eight site visits during August–September); and briefly appeared near the nest in May, July and August 2012 but did not attempt to breed (confirmed by ~20 site visits between June and mid October). As the area filled with houses, the eagles' patch became increasingly subject to traffic, people walking and cycling etc., with the prospect of intensified sportsfield activity (including at night under lights) as well as existing use by model aeroplane enthusiasts. The bushland patch containing the nest (and productive Osprey and Brahminy Kite *Haliastur indus* nests) was zoned Environmental Management (E3; certain development activities permitted with consent) by Tweed Council in its draft Local Environment Plan of 2012. In 2013 there was no Sea-Eagle activity at the nest (F. Hill pers. comm.). Overall, this pair's breeding productivity in 2010–2012 was below normal (one young in three pair-years, or 0.33 young/year).

Noosaville

During the planning stages for a proposed housing estate, *circa* 2003, a long-established Sea-Eagle nest was found in forest within 100 metres of the proposed housing precinct. The nest was on land designated as public open space, i.e. recreation. The following conditions were required by the local council and the proponent's fauna management plan (JWA 2004):

- nest tree protected from physical disturbance, no development within 30 metres of the tree;
- no construction work or development activities within 100 metres of the nest between 1 May and 31 October each year (i.e. Sea-Eagle breeding season at that latitude);
- an ecologist to monitor eagle activity immediately before and during the breeding season, nest tree inspected every two months during site works and every four months after site works (within 100 m) are completed;
- neighbourhood park (containing the nest tree) managed for passive use only (no facilities, i.e. water/tables/barbecues/bins, provided on site), minimal play equipment and associated grass areas located as far as possible from the nest tree, no dogs permitted, all trees (>30 cm dbh) in the park retained;

- human presence near the nest tree (if potentially disturbing to the eagles) managed by signage, fencing and a suitably distant pedestrian track with strategic (low-impact) viewing points;
- fuel raked 2 metres from the nest tree before any prescribed fire;
- provision to modify the management or construction activities if there is evidence of disturbance to the nesting eagles.

In August 2010, a local resident and JWA ecologist(s) confirmed that the nest was not being used that year, and road construction and clearing of building envelopes were therefore permitted to commence. By December 2012, when all houses in the subdivision were well established, there was no sign of the nest or Sea-Eagle activity (N. Evans pers. comm.). However, there was much potential nesting habitat remaining in surrounding environmental parks and State Forest.

Curtis Island

The eagle nest concerned was a deep, long-established nest, in native forest (Figure 4). In late September 2011, ecologists prepared a species management plan for the nest, to ensure that negative impacts were minimised and activity complied with Federal and State conditions of approval (e.g. a 100-m exclusion zone around the nest), associated with development of the pipeline. They determined when it would be 'safe' (for the eagles) for works to commence near the nest, i.e. after the young had fledged and would no longer be attached to the nest. The proponent engaged regular monitoring of the nest, and waited until the nest had been fully vacated before commencing the works. It was intended to cover the nest, to prevent it from being used in the 2012 season, in the hope that an alternative nest would be used. The ecologists recognised the risk of one failed breeding season for that pair, a temporary impact. Erring on the side of caution, they waited several months past the fledging date while monitoring the situation.

Covering the nest was deemed an unsafe activity and likely impossible, so the proponent tried to reduce the exclusion zone from 100 to 10 metres. This request was granted by the Queensland Department of Environment and Resource Management, but not the federal Department of Sustainability, Environment, Water, Population and Communities. Meanwhile, a further attempt was made to deactivate the nest by hauling a marine buoy into it in early April 2012 (Figure 4). To late May, no eagle activity was observed and the nest was pronounced 'successfully deactivated'. Subsequently, the eagles were seen in the general area, but there is no further information on whether they nested elsewhere, successfully or otherwise (B. French pers. comm., October 2012). That is, monitoring by the proponent did not extend to answering the question about impact on the eagles' breeding success in 2012.

Port Stephens

In mid February 2000, a large raptor nest was found in bushland, adjacent to human settlement, which was proposed for low-density rural-residential subdivision and an access road passing 50 metres from the nest. The proponent's concern was whether it was an Osprey nest, i.e. belonging to a state-listed *vulnerable* species subject to the provisions of the *NSW*

Figure 4. *White-bellied Sea-Eagles' nest, Curtis Island (Qld.), April 2012, with marine buoy installed to prevent breeding.*
Photo: Bruce French

Threatened Species Conservation Act, and therefore requiring the road to be moved to 100 metres from the nest. The nest proved to be that of White-bellied Sea-Eagles. Hence, no special provision was made for it, as the species is not State-listed and the ramifications of the then new *Environment Protection and Biodiversity Conservation Act 1999* were yet to evolve, with respect to federal listing of 'Migratory' species. (In this case, meaning subject to an international treaty: the China–Australia Migratory Birds Agreement, covering special protection for species shared by both countries). However, the proponent was willing to maintain a 100-metre buffer from dwellings, and to retain the best old-growth eucalypt forest in a conservation zone.

The development, with road 50 metres away, proceeded on the assumption that there was other available breeding habitat and potential nest sites in adjoining bushland lining other estuaries on the bay. Google Earth imagery suggested that there was sufficient remaining habitat and alternative nest sites for the affected pair, but the remaining bushland in the area is now much more disturbed. This case is another example of the incremental development pressure on the nest sites and breeding habitat of eagle pairs on the subtropical east coast (see also O'Donnell and Debus 2012), while an extra layer of protection under the *TSC Act* (thus giving the *EPBC Act* Migratory listing more strength) is lacking.

Mt Cottrell

A pair of Sea-Eagles built a nest at Pinkerton Forest in 2009, and raised two young in that year and one in 2010. The land immediately to the north, 200 metres from the Sea-Eagle nest, was then proposed as a landfill. The proposal would have involved earthmoving machinery and heavy trucks frequently passing 200 metres from the eagle nest, and hence chronic disturbance to any eagle breeding attempts over the life of the landfill. Local citizen groups and authorities opposed the project and the application was withdrawn, owing to the many conditions imposed. The eagles showed some initial interest in the nest site early in the 2011 season, but did not nest there; no alternative nest, or evidence of fledging, in the wider area was found through 2011, nor in the 2012 season (P. Gibbons pers. comm.). However, two adult Sea-Eagles were observed soaring over a lagoon at Pinkerton Forest in October 2012 (D. Akers pers. comm.).

In 2012, two Wedge-tailed Eagles *Aquila audax* reoccupied a previous nest site of this species in Pinkerton Forest (though not the Sea-Eagles' nest). Evidently, there was competition for a nest site in this forest remnant, and the Sea-Eagles were excluded in 2012. Perhaps the Sea-Eagles only occupied Pinkerton Forest while the Wedge-tailed Eagles were absent (an increasingly common interaction in Tasmania: N. Mooney pers. comm.).

Sydney Olympic Park

The history of this pair of Sea-Eagles, the only known breeding pair within the Sydney metropolitan area, is given elsewhere, in the popular and online literature (see Appendix 1). (At the time of going to press, another pair with nest and chick had been discovered in bushland on Middle Harbour: A. Ximenes pers. comm., Oct. 2013.) After several eagle deaths through the 1990s at Homebush Bay, and poor breeding success and fledgling survival in the decade to 2003, both adults died during nesting activities in 2004 and autopsies revealed high tissue levels of dioxins and furans (Manning *et al.* 2008). In the 2008 breeding season the male's wing became caught up (in fishing gear?), his health deteriorated and he disappeared, being replaced by a new male. Later, the juvenile was found injured and died in care soon after fledging. Dioxins and other persistent organic pollutants were implicated in the eagle deaths. Finally, after clean-up of toxins in Homebush Bay, the eagles' fortunes improved and the EagleCAM project was initiated to monitor the nest. The pair nested successfully each year since EagleCAM began. Nevertheless, in some years the juvenile disappeared early in the post-fledging period, suggesting that it may have died before independence. Owing to EagleCAM, and the site being visible from BirdLife Australia's Discovery Centre and regularly patrolled by park rangers, the nest is effectively under constant protective surveillance (and the pair has habituated to human presence).

Early in 2011 the eagles' nest collapsed, and a platform replacement was considered but rejected (in light of the Townsville and Coffs Harbour experiences). The eagles built a new nest in the same tree, and tolerated people climbing to maintain the video equipment outside the breeding season. However, in 2011 one of the chicks died in circumstances suggesting possible secondary poisoning from a chemical used to control feral pigeons and Common Mynas *Sturnus tristis* in nearby urban/industrial areas. In 2012 the eagles built a new nest 70 metres farther into the forest, and tolerated installation of a ground-based camera and a tree-mounted camera approximately 20 metres from the nest. Two young were raised, until at eight weeks old they became entangled together in fishing-line in the nest, with the hook embedded in the gullet of one chick and the line constricting its leg. Prompt veterinary intervention, including temporary removal of the chick and surgery to remove the hook, was successful, and both eaglets fledged (Anon. 2012; Hutchinson 2013). In 2013, the adults refurbished the nest and laid eggs, but by September the eggs were overdue to hatch and were found to be infertile (S. McGregor pers. comm.); the eggs are being tested for toxins.

CONCLUSIONS

Townsville

The initial success of the Bunnings case is attributed to the fact that the entire nest structure was moved intact, only a short distance, to a similar, semi-natural site amid a sheltering tree canopy. At least one of the pair must also have been unusually tolerant of human activity in the carpark. Eventual desertion of the nest was associated either with a change of mate (with the new eagle less tolerant of the Bunnings site) or the artificial site becoming less accessible with encroaching foliage, and the site becoming more disturbed by increased human activity. The eagles at the new site (Ross River) were also willing to build near existing human activity, to which they were probably habituated. Nevertheless, this case gives no confidence (a) that Sea-Eagles will necessarily accept a 'Bunnings' type scenario elsewhere, or build a new nest on an artificial platform substituted for an established nest tree; or (b) that nesting Sea-Eagles will tolerate the sudden, novel disturbance of creating a new development nearby. However, Bald Eagles *Haliaeetus leucocephalus* sometimes use artificial sites in North America (Millsap *et al.* 2004; S. McGregor pers. comm.), e.g. a collapsed tree-nest shored up with a platform built into the tree, or an artificial tower and platform with a decoy stick-nest structure installed to attract them. However, Grubb (1995) noted that artificial nests in new locations do not readily attract Bald Eagles, which tend to use artificial nests that only replace fallen, recently active nests.

With hindsight, an exclusion zone should have been imposed around the Bunnings pole, and another issue is that the pole is of fixed height whereas the adjacent trees continue to grow and overhang the nest. The site adjacent to Bunnings has since become subject to a further development approval, including diversion of a nearby creek.

Coffs Harbour

The precautionary approach, of encouraging the eagles to nest in safer surroundings, was considered the most cost- and labour-efficient, and most effective, solution to the problem of the eagles' active nest(s) being acutely disturbed, and ultimately destroyed, by advancing highway works. The 2010 fledging results vindicated the approach taken, and the forced moves in 2011 were also vindicated by the eagles' subsequent choice of a safer site and hatching of chick(s). The 2011 nest failure could not be directly attributed to quarry activity. However, the energetic cost of repeated displacement and rebuilding, and possibly delayed laying, may have been factors, although Sea-Eagle nests sometimes fail for natural reasons (e.g. Debus 2008; Corbett and Hertog 2011; Dennis *et al.* 2011b), and in this case goanna predation was suspected. The outcomes for 2012 and 2013 suggest that the proximity of advancing quarry works was too disturbing for the eagles to breed at their 2011 nest, and they either skipped a year (as sometimes happens naturally with large eagles) or used a new, undiscovered nest. Bald Eagles are especially disturbed by explosions and low helicopter flights, with the flushing response dependent on distance (disturbance being greatest at <1 km; Stalmaster and Kaiser 1997).

Strathpine

This eagle pair, apparently habituated to chronic human activity in the form of quarrying, returned to the nest site after acute disturbance (forest clearance) in the non-breeding season, and successfully bred in the following two years in the much-reduced patch of nesting habitat. This willingness may have been facilitated by the exclusion zone on the suburban boundary of the patch, and the continued existence of forest between the nest and foraging grounds. However, the long-term (post-2013) viability of the nest, only 50 metres from the housing estate, remains to be determined.

Tweed Coast

Despite the zoning of the eagles' nest patch as E3, and the eagles' initial tolerance of disturbance, their breeding attempt failed in 2011 and they did not breed in 2012, concomitant with increasing development and human activity around their nest. Thus, this pair suffered reduced breeding success with increasing disturbance within 200 metres of the nest. Rezoning of their patch to E2 (Environmental Conservation; limited developments permitted with consent) is desirable, but likely to be too little, too late to mitigate impact on the eagles' breeding success at that nest site. Google Earth imagery reveals that there is currently alternative breeding habitat available in the area, more remote from advancing urbanisation, to which the pair could relocate. In 2013, the pair had indeed abandoned the nest and presumably relocated to a less disturbed site.

Noosaville

The Sea-Eagles ceased using the nest before development activities commenced, but the reason is unclear; sustained human presence and activity (e.g. land survey, pegging-out) may have encouraged them to use an alternative site in nearby, less disturbed forest. The management measures did not facilitate the eagles' return to the site after major disturbance had ceased, and the abandoned nest disintegrated. However, it cannot be said that the general 30-metre buffer, or 100-metre exclusion zone during the breeding season, were inadequate, because events did not proceed to a test case of these buffer zones.

Curtis Island

The course of action was vindicated, in that in 2012 the eagles did not attempt to nest in their original nest in what had become a 'danger' zone (i.e. likelihood of breeding failure so close to the works zone). However, although the eagles continued to be seen in the general area, there is no knowledge of their subsequent nesting outcome: a shortcoming of the proponent's monitoring process. Furthermore, with the departure of the eagle consultant, the project's agents were not sufficiently skilled to find a new nest or monitor effectively (e.g. the notion that fledged Sea-Eagles might simply be small versions of the adults).

Sydney Olympic Park

With remediation of toxin levels in Homebush Bay, the eagles appear to have recovered from the indirect human impact of pollution of their hunting grounds by past chemical manufacture on the shore. However, dispersal and survival of juveniles is undetermined, and their survival may be poor in such a highly urbanised area. With respect to EagleCAM, the eagles have tolerated benign human activity, related to camera installation and maintenance, and discreet observation from the ground. They also built a new nest, at the evidently highly preferred site of the old nest that collapsed, and bred successfully in that year although they built a new (successful) nest in 2012. Despite the species' reputation for sensitivity, the eagles have habituated to limited, cautious human activity, and have become a powerful icon species for public awareness and education, with over two million online, global viewers of the 24-hour, live-streaming to the Net during the breeding cycle.

Nevertheless, the fortunes of this unique urban pair are precarious, with breeding failure in 2012 narrowly averted by direct human intervention, and infertile eggs in 2013. The case of nestling entanglement in fishing gear may be a symptom of a more widespread problem for Sea-Eagle populations generally.

Management implications

The five closely monitored cases illustrate the resilience and tenacity of at least some Sea-Eagle pairs on the subtropical eastern Australian coast, where nests are in tall trees, high above any disturbance and, in some cases, out of line of sight of the disturbance. However, even though the eagles habituate to routine, existing human presence and activity, it is less likely that they will tolerate sudden, novel disturbance (e.g. forest clearance, highway or urban construction) close to their nest sites (e.g. for the Bald Eagle, see reviews by Dennis *et al.* 2011b, 2012). Furthermore, nests in trees exposed by clearing suffer lower breeding productivity than those sheltered and visually screened within the forest (Emison and Bilney 1982; Dennis *et al.* 2011b). Mitigation strategies for eagle nests threatened by development should therefore be conservative, until there are more empirical data on the eagles' responses to acute disturbance and to mitigation measures. Artificial platforms (as for Ospreys, e.g. Moffatt 2009) are unlikely to be a viable strategy for this species, and sufficient natural nest sites and breeding habitat, with a choice of alternative sites, should be retained and protected wherever possible. Sea-Eagles are less tolerant and more demanding than Ospreys in their nest-site requirements (e.g. Marchant and Higgins 1993); therefore, buffer zones around nest trees should be more generous than for Ospreys (i.e. 500 m, and 1 km in line of sight, during the breeding season, as advocated for threatened Tasmanian eagles in forest: Threatened Species Unit 2006).

In the region concerned, Sea-Eagles show a range of reactions to disturbance, and tolerant eagles are perhaps the most valuable individuals. Thus, every effort should be made to protect their productivity, to allow the Sea-Eagle population to adapt. Sea-Eagles are also able to shift their nest sites successfully, if there is sufficient alternative habitat in their core territory or elsewhere in their home range. However, such shifts forced by removal or compromise of nest trees could lead to conflict (and hence breeding failure) with neighbouring pairs, which may not have such options. Where individual or isolated nest trees (which have limited lifespans) are well protected, groups of suitable trees should also be preserved as alternatives, and authorities and community groups could consider planting suitable trees as future recruits. Finally, it is important to distinguish between incidental and directed disturbance, i.e. eagles will often tolerate disturbance as long as it is not focussed on them. People staring and pointing is more intrusive (perceived as aggressive), and climbing to nests even more so; aerial survey by fixed-wing aircraft is a better way to determine nest contents (N. Mooney pers. comm.).

These various cases illustrate the ongoing pressures of landscape-changing developments on individual pairs of Sea-Eagles, and highlight a flaw in the protective legislation for low-density species with large home ranges. Some cases also illustrate a lack of willingness and/or capacity of proponents to monitor their impacts or mitigation. The *EPBC Act* assessment guidelines for Migratory species ask questions about impact on 'important habitat' (i.e. habitat critical at certain life-cycle stages, or at the species' range limit, or where the species is declining) for an 'ecologically significant proportion' of the population. For Sea-Eagle habitat, individual development cases affect single pairs only, and data are insufficient to demonstrate a local or regional decline over time. However, incremental loss of nesting pairs (or their productivity) could eventually lead to a significant impact on the local or regional population (e.g. Dennis *et al.* 2011a,b). Therefore, future *EPBC Act* assessments for this species, where it is not yet State-listed, should factor in cumulative impacts.

Even if some eagle pairs are displaced but rebuild in other available habitat, some near-urban pairs will eventually have no safe breeding habitat left. For instance, there appears to be a difference in Sea-Eagle breeding density between the urbanised Gold Coast (Qld) and the less urbanised Tweed and Clarence coasts (NSW) (O'Donnell and Debus 2012). Given the longevity of adult eagles and the presence of non-breeding mobile birds, reduced breeding productivity or loss of breeding pairs may take years to manifest as a population decline; meanwhile, areas such as the east coast may become a population sink for the species. Lost or discarded fishing gear is likely exacerbating the problem, and requires management by wildlife authorities and land managers, e.g. via regulation, and by extension programs to encourage fishers to be more responsible.

The human population is predicted to double on the New South Wales north coast in two decades (Prof. D. Brunkhorst in O'Donnell and Debus 2012), and most of the estimated Sea-Eagle population of approximately 800 pairs in NSW is located on the coast (Debus 2008; see Appendix 2). As predicted by O'Donnell and Debus (2012), the Tweed Coast is following the Gold Coast (e.g. the Pottsville Sea-Eagle case), with parts of the Tweed Coast northwards from Pottsville now rapidly changing under advancing urbanisation, compared with the late 1990s. Such changes are permanent. Based on indicative trends in impacts on nesting pairs (this study), and an estimated generation time of 15–18 years for large eagles (Garnett *et al.* 2011), a loss of 30 percent of breeding pairs from NSW in three generations (the next 45–55 years) seems plausible. Invoking the precautionary principle, listing of the White-bellied Sea-Eagle as *vulnerable* (*TSC Act*) should be considered, as it may satisfy criteria A3b,c and C1 of the IUCN Red List assessment criteria: population reduction (30% in three generations) suspected to be met in the future, based on an index of abundance and decline in habitat quality; and a small population (<10 000 individuals) and estimated continuing decline of at least 10 percent in three generations (see Garnett *et al.* 2011). As a sentinel species for threatened coastal ecosystems, the eagle's enhanced protection at state level would deliver broad biodiversity benefits (see Sergio *et al.* 2006, 2008), and greater strength to its conservation listing and attendant international obligations under federal legislation. Such is the success of EagleCAM (Appendix 1) that the wider community is likely to expect the highest level of protection, for what has become a highly popular and internationally renowned icon species.

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Appendix 1

Literature on the Sydney Olympic Park White-bellied Sea-Eagles (EagleCAM).

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Appendix 2

Estimate of the White-bellied Sea-Eagle population.

The basis of the estimate of approximately 800 pairs of Sea-Eagles in NSW was given elsewhere, with regional breakdown, partly from extrapolation of sample densities (Debus 2008); it included the rivers and wetlands of the coastal drainages, tablelands and the Murray-Darling Basin. The figure of approximately 600 pairs on approximately 1200 kilometres of NSW coast (at a continental scale) included, as stated, the river valleys of the coastal plain (which averages ~50 km wide); it thus does not imply one pair per two kilometres of coastline. Furthermore, the total length of coastline is dependent on scale (e.g. Thurstans 2009a). As a cross-check, there are an estimated 200–220 pairs in Tasmania (Threatened Species Section 2006); 70–80 pairs in South Australia (Dennis et al. 2011b); and conservatively 100 pairs in Victoria, with approximately 50 known pairs and potentially double that number in East Gippsland alone, and only 1–1.5 kilometres between some pairs (Bluff and Bedford 2011), or perhaps 200 pairs in Victoria overall. The SPRAT estimate (www.environment.gov.au/sprat) of greater than 500 pairs in Australia, based on one pair per 40 km of coastline (of ~20 000 km), was self-rated as of low reliability and likely a significant underestimate. Extending the NSW estimate (Debus 2008) proportionally, there may be at least 2500 pairs, including on islands, in Queensland. Extrapolating from approximately 40 pairs in two small sample areas of the Northern Territory, and 1–6.5 kilometres between pairs (Corbett and Hertog 2011), there may be at least 1000 pairs in the Territory. Extending the South Australian figure proportionally to southern Western Australia, and the NT figure likewise to the Kimberley, there could be at least 1000 pairs in Western Australia. Thus, there may be 6000 pairs in Australia, or an order of magnitude greater than the SPRAT estimate (which has not been updated since 2007 and has not used the Sea-Eagle studies published since that time). A revised national estimate is more in line with a global estimate of the low tens of thousands of individuals (Ferguson-Lees and Christie 2001), of which Australia might share one-third on the basis of occupied global range. Thus, the NSW estimate of 800 pairs (against the dated SPRAT estimate of >500 pairs nationally) should not be taken to imply that NSW is a stronghold, has a concentration of pairs, or an elevated population or density over other states.

Addendum: legal status of the White-bellied Sea-Eagle

Since this paper was proofed, it was announced that the White-bellied Sea-Eagle has been delisted from the EPBC Act 'Migratory' schedule, thus removing the layer of federal protection and perhaps, therefore, adding weight to the case for listing as vulnerable in NSW (TSC Act). For further details see Boobook 32 (2014), pp. 4, 16 and 28.

Corella, 2014, 38(3): 63-70

Modelling the nesting habitat requirements of the Wedge-tailed Eagle *Aquila audax* in the Australian Capital Territory using nest site characteristics

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Nest site characteristics of the Wedge-tailed Eagle *Aquila audax* were investigated during the 2011 breeding season within the Australian Capital Territory (ACT). Our objectives were to determine the nesting habitat requirements of this species in the ACT by surveying nest sites and identifying differences between habitat characteristics of nest trees and reference trees and active and inactive nest sites. A landscape model was created using maximum entropy distribution modelling (MaxEnt), predicting suitable nesting habitat for Wedge-tailed Eagles by extrapolating field measurements. This study found that during the 2011 breeding season Wedge-tailed Eagles in the ACT showed a preference for north-east facing aspects (P <0.01). Nests were located midslope, at elevations between 457 and 777 metres on slopes less than 30 degrees. Nests averaged 13 ± 3 metres above the ground (range 5–19 m, n = 34), in trees averaging 18 ± 3 metres tall (range 11–26 m, n = 34). Our results agree with previous research on Wedge-tailed Eagles in that the species chooses the largest trees available by height (P <0.0001) and girth (P <0.0001). Distance to urban areas from nests was measured using GIS spatial analysis, and revealed active nests to be on average 2850 metres (± 1.70 m) (range 350–7100 m) from built-up areas. The mapping and modelling applications used in this study identified the Molonglo and Murrumbidgee River corridors as essential breeding and foraging habitat for the Wedge-tailed Eagle. These applications can be used to aid management for the conservation of the Wedge-tailed Eagle, and species of concern such as the Little Eagle *Hieraaetus morphnoides* by identifying potential areas of nesting habitat and assessing the risks of future urban development.

INTRODUCTION

Despite its exceptionally heavy persecution up until the late 1970s (cf. Leopold and Wolfe 1970) and continued attrition through persecution and accidents with human infrastructure, the Wedge-tailed Eagle *Aquila audax* is common throughout the Australian mainland, playing an important ecological role as a top predator and scavenger (Mooney and Holdsworth 1991). There has been much research on the diet and breeding biology of the Wedge-tailed Eagle in the Australian Capital Territory (ACT) (cf. Leopold and Wolfe 1970; Olsen and Fuentes 2004; Fuentes and Olsen 2005; Fuentes *et al.* 2007; Olsen *et al.* 2010). In the ACT, Wedge-tailed Eagles lay their eggs around May to July and fledge young around October to December (given individual variation) (Olsen and Hatton unpub.). Known as the 'bush capital', the ACT has large areas of farmland and reserves of grassland and native bushland, ideal foraging habitats for raptors (Fuentes and Olsen 2005). The diverse habitat structure of the ACT allows eleven different species of raptors including Wedge-tailed Eagles to breed in close proximity to Canberra (Fuentes and Olsen 2005). The Molonglo Valley is an environmentally sensitive area that provides breeding and foraging habitat for many raptor species, including the Wedge-tailed Eagle (Olsen and Fuentes 2004; Debus 2008).

There have been many published studies on the nest site characteristics of raptors including Barred *Strix varia* and Spotted Owls *S. occidentalis* in Washington State (Buchanan *et al.* 2004), and Northern Goshawks *Accipiter gentilis* in Arizona (Reich *et al.* 2004). Nesting habits of the Wedge-tailed Eagle have been both described and modelled (cf. Mooney and Holdsworth 1991; Brown and Mooney 1997; Sharp *et al.* 2001; Collins and Croft 2007; Debus *et al.* 2007; Silva and Croft 2007; Foster and Wallis 2010), but there are gaps in our knowledge of the nest site characteristics of the Wedge-tailed Eagle (Foster and Wallis 2010), in the ACT and elsewhere. Foster and Wallis (2010) completed a descriptive study of nest site characteristics of Wedge-tailed Eagles in southern Victoria, using presence-only descriptive data rather than predictive data, having no control sites. Silva and Croft (2007) compared nest tree attributes of Wedge-tailed Eagles in western New South Wales with that of the mean of four reference (non-nest) trees. Sharp *et al.* (2001) pooled the data from currently active and previously used nests.

Wedge-tailed Eagles and White-bellied Sea-Eagles *Haliaeetus leucogaster* build the largest nest of any Australian tree-nesting birds (Olsen and Fuentes 2004). Wedge-tailed Eagles build stick nests which are commonly used for more than one year; typically refurbished in the early stages of the breeding cycle (Leopold and Wolfe 1970; Debus 1998). On rare occasions Wedge-tailed Eagles may nest on artificial structures such as electricity pylons (Debus 1998; S. Cherriman pers. comm.). It is asserted by many researchers that Wedge-tailed Eagles do not select trees based on species (e.g. Ridpath and Brooker 1987; Sharp *et al.* 2001), instead choosing the largest trees available by height and girth within suitable habitat (Debus 1998; Sharp *et al.* 2001; Collins and Croft 2007; Silva and Croft

2007). Tree height and girth (giving a measure of 'robustness') are important factors in nest site choice, as large trees provide stability for the nest, and if high in a tree on a slope, commanding views over the landscape for location of prey, competitors and potential nest predators (Sharp *et al*. 2001). Juvenile survival may depend on nest quality such as cover and stability, as well as prey densities and parental care (Collins and Croft 2007).

Debus *et al.* (2007) reported that Wedge-tailed Eagles prefer trees on the side of a gully at mid-slope, suggesting topographic position is a key factor influencing nest site selection. This is supported by earlier studies by Mooney and Holdsworth (1991) and Brown and Mooney (1997), who described that nest tree top height is typically just below the top of the ridge, and also found that important nest site characteristics included slope angle and shelter from prevailing wind. Foster and Wallis (2010) found Wedge-tailed Eagle nests were on slopes less than 30 degrees. Sharp *et al.* (2001) noted that elevation is a key element and may be more important than nest height within the tree, as it affords a view of potential nest predators and prey.

Reich *et al.* (2004) modelled the interaction between the nest location of Northern Goshawks and forest structure using spatial interpolation of habitat attributes at both active nests and randomly selected non-nest trees. Brown and Mooney (1997) modelled Wedge-tailed Eagle habitat in Tasmania using a data set of nest site characteristics, and found that modelling techniques can be used successfully to predict Wedge-tailed Eagle nesting habitat, an important part of conservation of the species amongst land development such as forestry. Modelling nest site characteristics has applications for forest management, to determine the potential habitat of Wedge-tailed Eagles when considering areas for clearing (Brown and Mooney 1997), and has been recommended by Foster and Wallis (2010) for future studies on this species.

Our study aimed to determine the nesting habitat requirements of this species in the ACT. Our objectives were to survey known nest sites to investigate any significant differences in nest site characteristics between nest trees and reference trees, and any topographic differences between active and inactive nest tree sites. This study follows on the recommendations of Foster and Wallis (2010) to incorporate statistical comparison of actual and potential nest sites, to better define the determinants of nest site selection. We aimed to use measured nest site characteristics to create a landscape model, predicting suitable nesting habitat for Wedge-tailed Eagles to determine important areas for conservation.

In addressing these aims and objectives we tested three hypotheses. Firstly, there would be no physical difference in tree characteristics between nest trees and reference trees. Secondly, there would be no difference in physical characteristics of nest sites between known nest sites and reference sites. This was tested using a regression of nest site characteristics against reference tree site characteristics. Thirdly, it was hypothesised that there would be no difference between physical characteristics of active nest sites and inactive nest sites. This was tested using a data set containing only nest trees; comparing nests in use during the 2011 breeding season with old nests from previous breeding seasons.

STUDY AREA

The study area was located within the ACT encompassing the city of Canberra (35°27'S, 149°12'E). The climate is characterised by warm to hot summers (January mean minimum and maximum 13–27.5º C) and cool to cold winters (July mean minimum and maximum -0.2–11.2º C), with relatively low rainfall (average annual rainfall 629 mm) (Bureau of Meteorology 2011*a*). Summer winds are generally from the east through to the north-west, and in winter westerly winds bring colder air over southern Australia (Bureau of Meteorology 2011*b*). Nest trees known to be used by Wedge-tailed Eagles in the study area include Yellow Box *Eucalyptus melliodora*, Blakely's Red Gum *E. blakelyi* and River She-oak *Casuarina cunninghamiana* (Fuentes and Olsen 2005; Fuentes *et al.* 2007).

METHODS

Terminology used in this paper

An 'active nest' is defined as a Wedge-tailed Eagle nest that contains eggs or young, is lined with fresh eucalypt sprigs, or has an incubating adult observed on the nest. An 'inactive nest' is a Wedge-tailed Eagle nest that has no signs of use by Wedge-tailed Eagles during the current study. 'Nest tree' is defined as a tree that contains a Wedge-tailed Eagle nest either currently or not currently in use, and 'non-nest tree' is a reference tree that has been randomly selected and does not contain a Wedge-tailed Eagle nest. 'Nest tree characteristics' include features of the tree containing the nest, such as height and species; 'nest site characteristics' include features of the landscape where the nest tree occurs, such as topography. Habitat in this context describes an area suitable for Wedge-tailed Eagles to nest and breed successfully, and includes tree and site characteristics. A territory is defined as that part of the home range used for foraging and breeding that is defended against competitors.

Field methods

Thirty-four Wedge-tailed Eagle nests, including eight nests active in 2011, were located in that year within the ACT during a pilot study. Stick nests built by Wedge-tailed Eagles were easily identified as they are much larger than other birds' nests (with the exception of the White-bellied Sea-Eagle) (Silva and Croft 2007). Previously recorded nest sites were located with a GPS, and the surrounding area was searched for new nests. Visiting nest sites was timed carefully to avoid risk of eggs or young being exposed to harsh weather or predators; Wedge-tailed Eagles are amongst the shyest nesting raptors in Australia and adults almost invariably leave the nest when approached by humans (Silva and Croft 2007).

At each nest site the location was recorded using a GPS unit (Garmin GPS72H; mean accuracy 6.04 ± 1.70 m) and a range of characteristics were measured. Slope angle, nest tree height and nest height above ground was measured using a clinometer and trigonometry. A range finder was used at 20 ± 1 metres from the base of the tree to calculate height with an accuracy of ± 5 per cent, due to different leaning angles and canopy shapes of trees (a sight to the top must be obtained). Tree diameter at breast height (DBH) at approximately 1.5 metres above ground was measured using a tape measure, aspect was recorded using a compass, and elevation from base of tree was recorded using

Table 1

Mean (± SD) nest height (m) above ground and tree height (m) for Wedge-tailed Eagles in the ACT.

	Nest height	Tree height	(*n*)
All nest trees	13 ± 3 (range 5-19)	18 ± 3 (range 11-26)	34
Active nest trees	14 ± 2 (range 10-17)	19 ± 2 (range 14-22)	8
Inactive nest trees	13 ± 4 (range 6-19)	18 ± 4 (range 11-26)	26
Reference trees	–	14 ± 4 (range 4-24)	97

Table 2

Number of nests of Wedge-tailed Eagle on slope category (lower, middle, or upper) in parentheses. Ranges of slope angles (degrees) within each category.

	Lower	Mid	Upper
Active nests	0 (2)	5–25 (4)	20–30 (2)
Inactive nests	0–20 (7)	<5–20 (12)	7–30 (7)

Table 3

Elevation summary for Wedge-tailed Eagle nest trees in the ACT. Figures are in metres.

Elevation	Min	Max	Mean	(*n*)
All nests	457	777	624	34
Active nest	464	777	595	8
Inactive nest	457	775	632	26

Table 4

Distance from active Wedge-tailed Eagle nest sites to urban areas (m) in the ACT.

Active nest site	Distance to urban areas (m)
1	420
2	3930
3	3270
4	3180
5	3210
6	1310
7	7100
8	350
Average distance	2850 ± 1.7

a GPS unit. Nest tree species were also recorded. Topographic habitat information was entered into a database for modelling using MaxEnt (Elith *et al*. 2011). To determine if Wedge-tailed Eagles were selecting particular tree characteristics, we compared nest sites with reference sites in a paired design. At each nest site, three reference non-nest trees were randomly selected by rolling a 12-sided die, the numbers 1–12 denoting 30-degree increments on a compass, from which a heading was obtained to walk to the nearest mature tree (of at least 15 centimetre DBH) within 50 metres in that direction. The same measurements and observations were made for the reference trees, excluding that of nest height.

Data analysis

Nest site locations were uploaded from a GPS into ArcGIS v9.3 to calculate mean distances between active nest sites and urban areas. The computer program 'MaxEnt' was used to predict the suitable habitat for Wedge-tailed Eagles within the study area. MaxEnt is a method to calculate species distributions from presence-only species records (in this case presence of nests) (Elith *et al.* 2011). Species distribution models (SDMs) estimate the relationship between species records at sites and the environmental and/or spatial characteristics at sites (Elith *et al.* 2011). MaxEnt provides two probability densities: one estimated from the presence data, and one from the landscape (Elith *et al*. 2011). This was used to model the presence data from nest sites and the habitat parameters. Four environmental variables were considered as potential predictors of suitable habitat for Wedge-tailed Eagles: Elevation, Slope, Aspect and Distance to urban areas. Thirty-four nest sites (including active and inactive nests) were used as presence-only species records.

Data were analysed using the statistical program 'R'. Data from both active and inactive nests were pooled and used in the nest site characteristics analysis to compare with the reference trees. A mean was calculated from the parameters of the three reference trees measured, to use as a control for absence data because they were very similar, and all normally distributed. Characteristics were compared between nest trees and reference non-nest trees using a Welch Two Sample t-test (not normally distributed data) for the variable tree height, and a paired t-test for the variable DBH. Tests were run between active nest trees (n = 8) and inactive nest trees (n = 26) to determine if any of the variables Slope, Nest Height, Elevation, or Aspect could explain nest site selection. Data were checked for normality using histogram plots. Nest aspects were grouped into four classes to run the regression (E: 45–135º; S: 135–225º; W: 225–315º; N: 315–45º); and circular statistics using Watson's Two-Sample Test of Homogeneity were run on the variable Aspect after converting the data to radiance format. For all parameters we report the mean plus/minus one standard deviation and the range. A significance level of five percent was used for all statistical analyses. Box plots were used to highlight any significant differences, and a regression analysis was performed to explore relationships between variables.

Limitations

Leopold and Wolfe (1970) provided the first account of Wedge-tailed Eagle breeding density in the ACT, a study conducted over a four-year period. It is not always possible or feasible to check every known site and extensively search for more sites. The factor of distance to urban areas used in the MaxEnt model does not take into account that currently unused nests may have been at greater distances from urban areas when they were active (i.e. the nests may have been abandoned because of encroaching urban areas). The modelling used in this study does not account for inter- or intra-specific competition, such as territoriality (Reich *et al.* 2004).

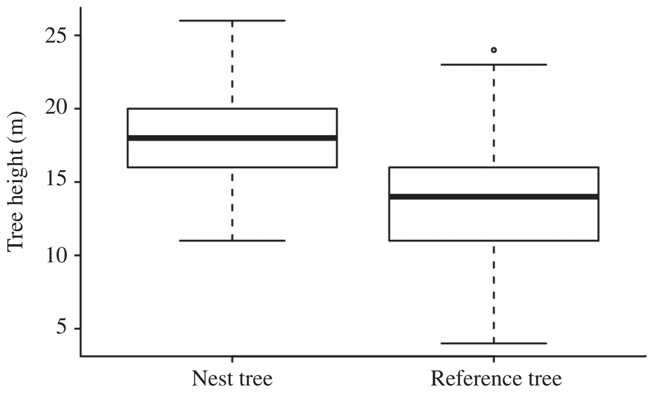

Figure 1. *Box and whisker plots for mean tree height (m) of Wedge-tailed Eagle nest trees and reference trees in the ACT. Boxes indicate median and 25th and 75th percentiles, whiskers represent the lowest datum still within 2.5 IQR of the lower quartile, and the highest datum still within 2.5 IQR of the upper quartile.*

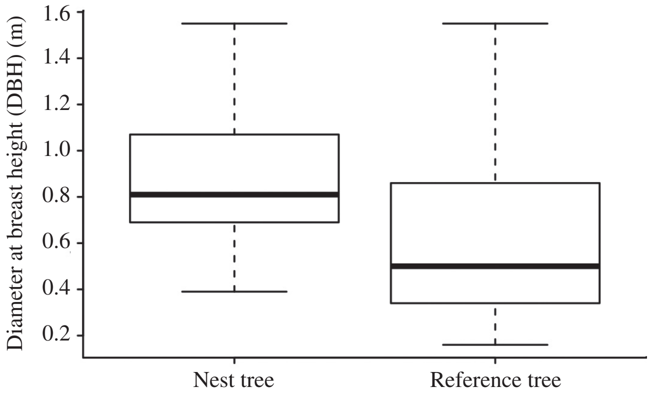

Figure 2. *Box and whisker plots for diameter at breast height (DBH) of Wedge-tailed Eagle nest trees and reference trees in the ACT. Boxes indicate median and 25th and 75th percentiles, whiskers indicate the lowest datum still within 2.5 IQR of the lower quartile, and the highest datum still within 2.5 IQR of the upper quartile.*

RESULTS

Comparison of nest trees and reference trees

Nest trees were significantly taller than reference trees (95% confidence interval = 3.2, 6.3; Welch test statistic = 6; df = 65.4; *P* <0.0001) (Table 1; Fig. 1; Appendix 1). Nest tree mean height was 18 metres (± 3 m) (range 11–26 m) and reference tree mean height was 14 metres (± 4 m) (range 4–24 m). Nests averaged 13 ± 3 m above the ground (Table 1; range 5–19 m). Nest tree DBH was significantly greater than reference tree DBH (95% confidence interval = 0.2, 0.4; paired test statistic = 5.4; df = 33; *P*<0.0001) (Fig. 2; Appendix 2). Nest tree mean DBH was 0.9 metres (range 0.39–1.55 m) and reference tree mean DBH was 0.6 metres (range 0.24–1.07 m). Statistical analysis found no significant differences between nest and reference trees for the variables Slope, Elevation and Aspect. All nest trees were on slopes less than 30 degrees (Table 2) at elevations greater than 400 metres (Table 3).

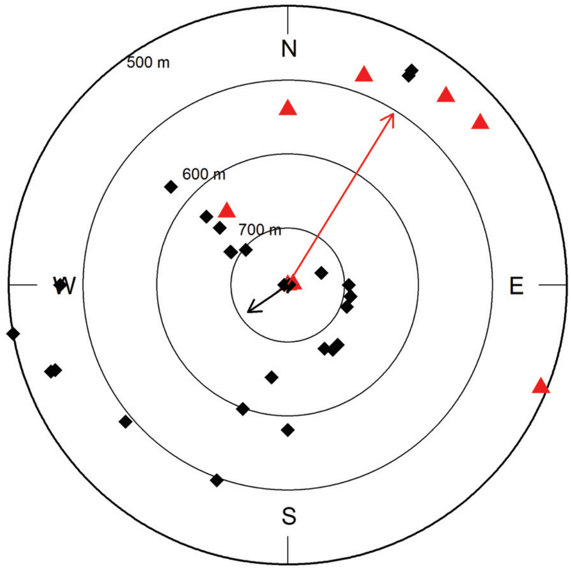

Figure 3. *Distribution of aspects of Wedge-tailed Eagle nests in the ACT: 34 nests on a schematic circular hill, for elevation (m) and aspect across the study area. Active nests are represented by red triangles and inactive nests are represented by black diamonds. Mean aspect direction of active nests (31° NE) is indicated by the red arrow and inactive nests (235° SW) by the black arrow; the length of the arrow determines the strength of the effect (Watson's test statistic = 0.29; P<0.01).*

Comparison of active nest trees and inactive nest trees

Regressions were run between active and inactive nest trees for the variables Slope, Nest Height, Elevation, and Aspect, with aspect being the only significant factor (Fig. 3; Appendix 3). Active nests showed a strong statistical relationship with aspect; however, the statistical relationship with aspect for the inactive nest trees was not strong (reflected by the length of arrows in Fig. 3). Active nest trees were found to be on a significantly different aspect from inactive nest trees, favouring north-easterly facing slopes (Fig. 3; mean aspect of active nests: 31º NE; mean aspect of inactive nests: 235º SW; Watson's test statistic = 0.29; *P*<0.01).

Spatial analysis and habitat distribution modelling

Nests averaged 2850 metres (range 350–7100m) from urban areas (Table 4). The MaxEnt model predicted potentially suitable Wedge-tailed Eagle nesting habitat (Fig. 4) (training data (Area under the curve, AUC) = 0.931; test data AUC = 0.896). Habitat below 550 metres in elevation was found to have the highest probability of presence. The MaxEnt model found that elevation was the most effective single variable for predicting suitable Wedge-tailed Eagle habitat, contributing 80 per cent towards the prediction of presence. The preferred elevation ranged from 200–1000 metres (Fig. 5). The second most effective variable for predicting suitable Wedge-tailed Eagle habitat (contributing 19.5%) was slope, with the predicted probability of presence increasing as the slope angle increased to a peak at 15 degrees, probability then tapering off. The other two environmental predictors (aspect and distance to urban areas) did not help to explain the presence of eagle nests.

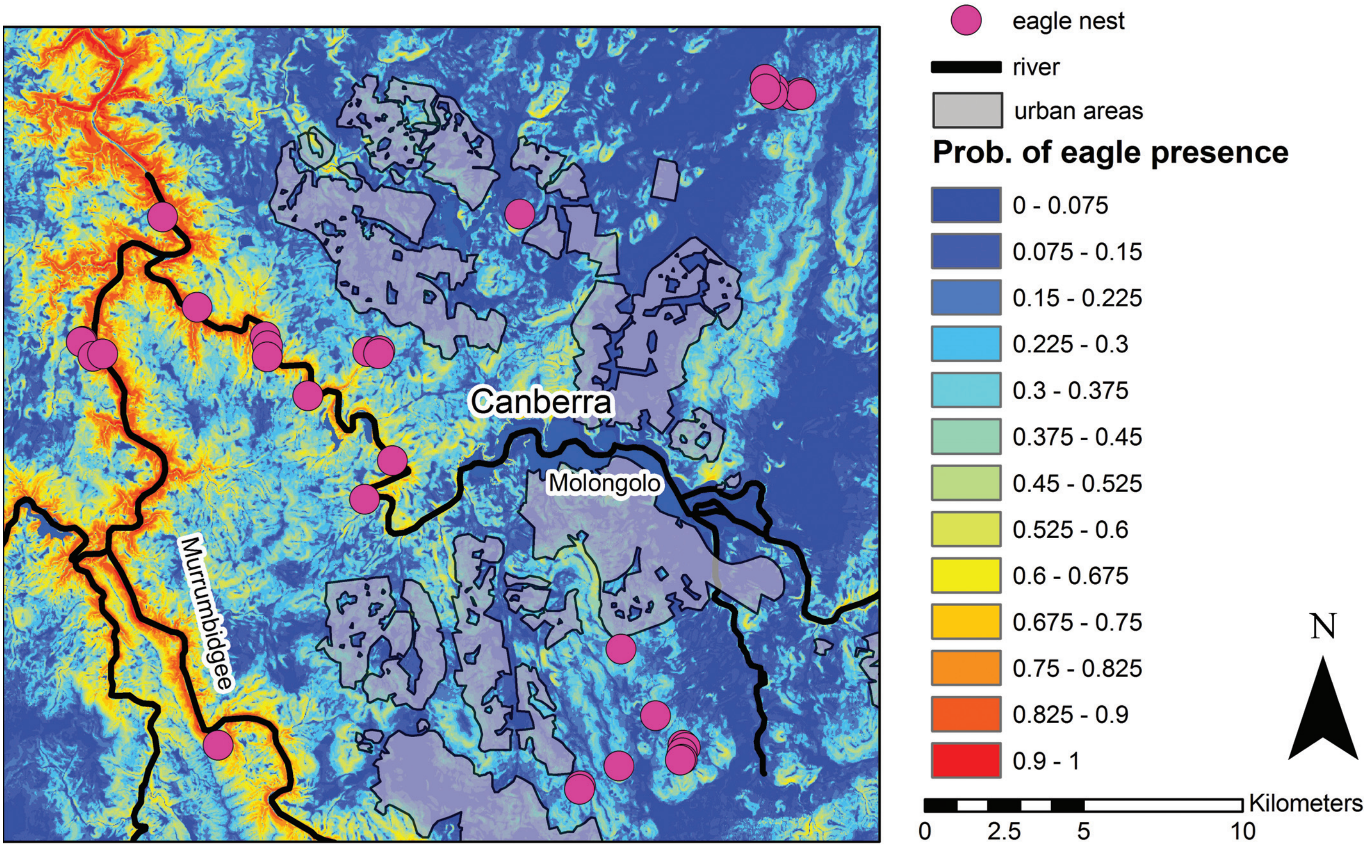

Figure 4. *Representation of the MaxEnt model's prediction of suitable Wedge-tailed Eagle nesting habitat in the ACT. 1 = Most suitable, 0 = Least Suitable. Warmer colours (reds, oranges, yellows) show areas with a higher probability of suitable habitat. Pink dots show the locations of eagle nests in the study area.*

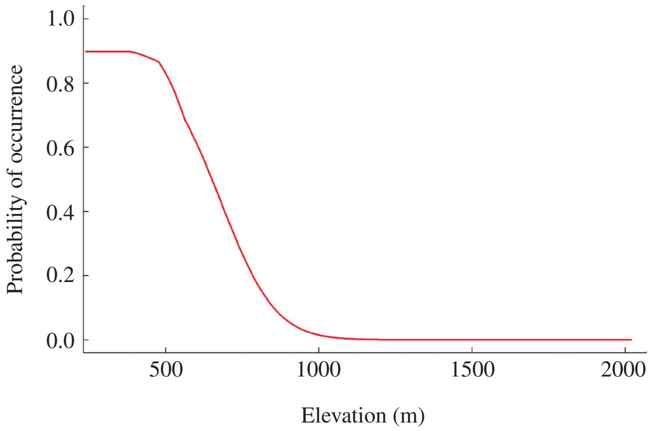

Figure 5. *Predicted probability of presence of eagle nests in response to elevation [m].*

DISCUSSION

Relationships between tree characteristics and nest site selection

Although significant relationships were not found between all variables comparing nest and reference trees, all habitat-related variables have been previously identified as important to Wedge-tailed Eagle nest tree selection (cf. Mooney and Holdsworth 1991; Brown and Mooney 1997; Sharp *et al.* 2001; Collins and Croft 2007; Silva and Croft 2007; Foster and Wallis 2010). Our results agree with many studies on Wedge-tailed Eagles, in that they choose the tallest available robust trees (Table 1; Fig. 1; Appendix 1) (Ridpath and Brooker 1987; Mooney and Holdsworth 1991; Sharp *et al.* 2001; Silva and Croft 2007). Our results concur with that of Mooney and Holdsworth (1991) in that trees selected by Wedge-tailed Eagles are also the largest available by girth (Fig. 2; Appendix 2). Wedge-tailed Eagles have no preference for a particular tree species (Appendix 4) (Ridpath and Brooker 1987; Sharp *et al.* 2001), although, as also found by Foster and Wallis (2010), all nests sampled in this study were in native tree species (*Eucalyptus, Callitris* and *Casuarina sp.*) more than five metres above the ground (Table 1; Appendix 4; mean nest height = 13 ± 3 m).

Relationships between topographic location and nest site selection

Choice of aspect for nest location may be determined largely by the prevailing wind direction (Mooney and Holdsworth 1991; Brown and Mooney 1997). The Canberra area has strong north-westerly prevailing winds and calm north-easterly winds. Our results support the findings of previous studies that nest trees are most often situated below ridge height on moderate slopes less than 30 degrees (Table 2) (Mooney and Holdsworth 1991; Brown and Mooney 1997; Foster and Wallis 2010). This may be attributable to providing shelter from wind and bushfires, the lee slope being less prone to wind-driven fire, although on a slope there may be more risk of the canopy catching fire for proximity is closer to the ground (Mooney and Holdsworth 1991; Brown and Mooney 1997; Foster and Wallis 2010). Our results showed that nest site selection is influenced by aspect; most active nests surveyed in the 2011 breeding season were situated on north-east facing slopes (Fig. 3). This finding supports the suggestion by Brown and Mooney (1997) that Wedge-tailed Eagles breed in nests on aspects sheltered from strong prevailing winds. In Canberra, this is particularly important for protection from cold westerly winds during the laying period (Bureau of Meteorology 2011*b*).

Sunlight may also influence choice of aspect. Foster and Wallis (2010) found that aspect was an important factor in that Wedge-tailed Eagles choose sites that shelter from afternoon sun. The mean temperature in the ACT has risen by approximately 0.15–0.20 degrees every decade between 1970 and 2010 (Bureau of Meteorology 2012). As Canberra's mean temperatures warm over time, Wedge-tailed Eagles may be showing a preference for aspects shielded from direct afternoon sunlight (Fig. 3). A north-easterly aspect may also provide eagles with direct access to morning thermals off the slopes, which are the first to warm with the rising sun from the east. However, these interactions require further investigation and a larger sample size of active nests.

Habitat distribution modelling

Computer modelling has been used successfully to predict Wedge-tailed Eagle nesting habitat (Brown and Mooney 1997). This study has created a model of suitable nesting habitat for Wedge-tailed Eagles in the ACT (Fig. 4). The MaxEnt model predicted elevation as the most important variable (Fig. 5). Silva (1998) identified that elevation may be more important than nest height within the tree, providing it is in combination with a good slope, as a view of the landscape to identify competitors, nest predators and potential prey is crucial to nesting success (Sharp *et al*. 2001). Nest elevations ranged between 457 and 777 metres (Table 3). Due to the location of most Wedge-tailed Eagle nests in the ACT being on hilltops and ridgelines, active nests at higher elevations generally had a larger visible area than those in valleys. Although nests at higher elevations afford a commanding view over the landscape (Sharp *et al.* 2001), we found that this was not a critical factor in nest site choice, as 13 nests were on slopes of five degrees or less, including two active nests on flat ground in the riparian zone of river valleys (Table 2). We observed eagles with active nests at low elevations using perch trees on ridge lines or laminar soaring along such where they could view both the nest and the surrounding area, thus compensating for the limited outlook from the nest site; although eagles nesting at higher elevations commonly use perch trees with vantage over their nest also.

Fuentes *et al.* (2007) found the average distance of Wedge-tailed Eagle nests in the ACT to suburbs was 1117 metres (± 251 m) (range 260–2000 m). We found that active nests in 2011 were at greater distances from urban areas, at an average 2850 metres (range 350–7100 m) (Table 4). One territory, surrounded by suburbs and a main road, was disturbed often in the past and has since been abandoned (J. Olsen unpubl. data). These findings suggest a trend for Wedge-tailed Eagles to retreat from expanding suburbia, as discussed by Debus (2008). However, we did find examples of tolerant pairs that were able to nest within close proximity to urban areas; when located in nature reserves that offered a level of protection from human disturbance. The two active nests closest to urban areas were at distances of 350 metres and 420 metres from such (Table 4).

Habitat modelling applications for conservation

The availability of nest sites is a factor that limits raptor populations (Buchanan *et al*. 2004). By describing the spatial distribution of Wedge-tailed Eagle nests and modelling the interaction between nest locations and topographic variables, it may be possible to predict the location of active nests in a given year (Fig. 4) (Brown and Mooney 1997; Reich *et al*. 2004). Although our study identified nest site characteristics, the availability of locations that can potentially support nests is not the only factor governing the distribution and abundance of a population (Reich *et al.* 2004). Careful consideration must also be given to factors including suitable foraging areas, territoriality and human disturbance, in particular urbanisation (Olsen and Fuentes 2004; Debus 2008; Foster and Wallis 2010).

As a long-lived species, Wedge-tailed Eagles show strong site fidelity, individuals often occupying the same territories for 40 years or more (Olsen and Fuentes 2004). Our results support the assertion that the Molonglo and Murrumbidgee River corridors are important nesting areas for the Wedge-tailed Eagle (Fig. 4), among many other species of raptors (Olsen and Fuentes 2004; Fuentes *et al*. 2007), yet these corridors have been proposed as areas for future urban development. Further urban development in areas identified in this study as actual or potential Wedge-tailed Eagle nesting habitat (Fig. 4) has the potential to also remove foraging habitat. This may displace pairs of Wedge-tailed Eagles and cause nesting failure, forcing them to seek new nesting habitat with the potential of encroaching on other species, such as the Little Eagle, listed as vulnerable in the ACT (Debus 2008; Olsen *et al.* 2010).

Further study

We have identified areas that may yield suitable nesting habitat for the Wedge-tailed Eagle in the ACT using habitat modelling (Fig. 4). From this analysis, further study could include:

1. Ground-truth our habitat predictions by searching the areas identified as suitable habitat for Wedge-tailed Eagle nests (Fig. 4).

2. Investigate distance to water as a determining factor in nest site choice, as our predicted habitat model reflected suitable areas along river corridors (Fig. 4). This relationship could be due to increased prey availability in these areas.

3. Further information is required on the home range and foraging habits of this species (Olsen and Fuentes 2004) to determine the impacts of disturbance on Wedge-tailed Eagles in the ACT. Knowledge of home-range size is useful to determine the number of nests and territories expected in a given area (Brown and Mooney 1997). Radio and/or satellite tracking is the most reliable method to define home-range and territory requirements (Olsen and Fuentes 2004; Debus 2008).

CONCLUSIONS

We reject the first null hypothesis, that there is no difference in tree characteristics between nest trees and reference trees, because significant differences were found between nest tree and reference tree height and DBH. We did not find enough evidence to reject our second hypothesis, that there is no difference in topographic characteristics between known nest sites and reference sites. For the site characteristics of slope, aspect and elevation no significant differences were found between nest trees and reference trees, as the reference trees were in the vicinity of the nest trees measured. We found that breeding Wedge-tailed Eagles showed a preference for north-east facing aspects, which may be attributable to shelter from prevailing wind or a warming climate. Owing to significant differences found between the aspect of active nests and inactive nests, we reject our third null hypothesis, that there is no difference between active nest tree sites and inactive nest tree sites. In summary, Wedge-tailed Eagles in the ACT choose the tallest and most robust (largest by girth) trees on slopes less than 30 degrees, at elevations above 400 metres, often on north-east facing aspects. Modelling analysis demonstrated that elevation was the strongest predictor for suitable nesting habitat, followed by slope. The modelling results of this study support the claim by Olsen and Fuentes (2004) and Fuentes *et al*. (2007) that the Molonglo and Murrumbidgee River corridors are important nesting areas for the Wedge-tailed Eagle, and show that modelling can be used to identify areas to focus conservation effort.

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Appendix 1

ANOVA table for tree height comparison of Wedge-tailed Eagle nest trees and reference trees.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	490.076	490.076	40.18	<.0001
Error	129	1573.435	12.197		
Corrected Total	130	2063.511			

Appendix 2

ANOVA table for DBH (diameter at breast height) comparison of Wedge-tailed Eagle nest trees and reference trees.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	2.115	2.115	21.47	<.0001
Error	130	12.813	0.098		
Corrected Total	131	14.929			

Appendix 3

Regression run through ‘R’ for Wedge-tailed Eagle active and inactive nest trees on the factors Slope, Nest height, Elevation, and Aspect.

P(>|Chi|)	Df	Deviance	Resid.	Df Resid.
NULL		33	37	
Slope	1	0.17	32	36.38
0.397				
Nest height	1	1.41	31	34.96
0.233				
Elevant	1	0.4	30	34.56
0.525				
Aspect	3	22.58	26	11.81
0.000				

Appendix 4

Species of measured Wedge-tailed Eagle nest trees and reference trees.

Species	Nest tree *(n)*	Reference tree *(n)*
Callitris endlicheri (Black Cyprus Pine)	–	2
Casuarina cunninghamiana (River Oak)	10	25
Eucalyptus blakelyi (Blakely’s Red Gum)	7	16
Eucalyptus bridgesiana (Apple Box)	4	6
Eucalyptus dives (Broad-leaved Peppermint)	–	6
Eucalyptus goniocalyx (Bundy)	–	1
Eucalyptus macrorhyncha (Red Stringybark)	1	6
Eucalyptus mannifera (Brittle Gum)	4	9
Eucalyptus melliodora (Yellow Box)	6	17
Eucalyptus rossii (Scribbly Gum)	–	8
Eucalyptus rubida (Candlebark)	1	2
Unidentifiable	1	–

Corella, 2014, 38(3): 71-74

Social group persistence over time in Brown-headed Honeyeaters *Melithreptus brevirostris*, as revealed by trapping records

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Brown-headed Honeyeaters *Melithreptus brevirostris* are commonly captured in groups in mist nets. Social network analysis was applied to multiple-capture data between 1986 and 2009 at a single banding site at Weddin Mountains, central western NSW, to infer the long-term persistence of a single social group of Brown-headed Honeyeaters at the banding site. Of the 162 individual Brown-headed Honeyeaters trapped at the site, 83 can be linked to a single social group that has persisted at the site through the entire 24-year study period. In this region, nomadism appears to be rare for this species.

INTRODUCTION

Flocks of Brown-headed Honeyeaters *Melithreptus brevirostris* of up to 15 individuals are a regular sight across their geographic range (Higgins *et al.* 2001). Their movement patterns are poorly known, with birds variously described as resident, locally nomadic, nomadic or part-migratory (Keast 1968; Frith 1969; Higgins *et al.* 2001 and references therein), although Griffioen and Clarke (2002) found strong evidence for "no large-scale migratory movement" for this species. Noske (1983) recorded cooperative breeding for Brown-headed Honeyeaters at Armidale in NSW, a general precondition for which is that the young birds remain with their family group until at least the next breeding season (Ford *et al.* 1988).

The simultaneous capture of several individuals in a single mist net during banding operations, and the subsequent simultaneous recapture of some of the same individuals, is relatively common. Boehm (1968) details an instance at Bower, South Australia, where nine Brown-headed Honeyeaters were trapped together in 1963, with four of those individuals subsequently trapped together (with eleven others of this species) in 1967, over four years later. Repeated trapping of these groups may suggest the existence of social groups at that place. Retrapping members of such a group could provide information on the persistence of social bonds between group members over time.

On 8 November 2009 a group of nine Brown-headed Honeyeaters was trapped in a single mist net at a long-term banding site at Holy Camp, Weddin Mountains, central NSW (33º53'53"S, 148 º00'11"E, elevation 413m). Initially, five birds, including a juvenile, were found in the net when it was checked, but during their removal a further four birds were attracted by calls of the trapped birds and flew into the net. Four of these nine birds had been trapped previously, and were aged 2+ (in the second year of life or older), 5+, 10+ and 14+ years old. These birds appeared to be part of a resident social group but this needed to be quantified so banding data collected over 24 years at Holy Camp was used to shed light on flock composition and persistence of social bonds.

METHODS

Holy Camp is an area of mixed woodland situated on shale soil on the lower east-facing slope of the Weddin Mountains, in temperate south-east Australia. The woodland canopy is dominated by *Eucalyptus spp.* and *Callitris glaucophylla*, with an understorey of wattles (*Acacia* spp.), hopbush (*Dodonea* spp.) and other shrubs, tending to open grassland in some areas within the site.

Bird banding was conducted about five times per year from 1986 to the present in an area of approximately 45 hectares. Banding trips were generally of two or three days' duration, and there were 107 banding trips covering all months of the year during the study period (1986–2009). Only data from 1986 to 2009 inclusive were used in this analysis. Standard ABBBS and morphometric data (species, gender, age, weight, head-bill length, wing and tail length) were collected, as well as data on primary wing moult (each primary feather scored as 0–5, after Lowe (1989)), brood patch (scored as 0–3 after Lowe (1989)) and net site. Trapped birds were aged, where possible, based on retrap durations or characters of the bird in the hand. Young birds of this species can be aged as juvenile, 1, 2 or 2- on the basis of plumage, eyelid colour and bill colour, while all other birds showing full adult plumage are known to be 2+ (Rogers *et al.* 1986). Very few individuals were sexed during banding, so sex differences cannot be explored here.

To gain a better understanding of flock composition and persistence, a social network analysis was performed, based on trapping records. Data, incorporating 136 individuals, were collated for 46 separate instances where birds were trapped in groups of two or more. Each individual bird was treated as a node in a network, and each instance where two birds were simultaneously trapped in the same mist net as a tie between those two birds in the network. This approach assumes that two birds simultaneously trapped in a net are associating. This assumption may not always hold, for example, where birds are trapped together near water, but this was not the case in this study. These social data were visualised using a Non-metric Multi-dimensional Scaling (NMDS) plot in NetDraw (Borgatti

2002). To provide further context to the NMDS social network time of first trapping (1986–1990, 1991–1995, etc.) was shown as different coloured markers and whether the bird was ever re-trapped by different shape of marker (square or circle).

RESULTS

In total, 162 individual Brown-headed Honeyeaters were trapped. Some individuals demonstrated remarkable site fidelity and longevity, being trapped up to eight times over periods of up to 13.6 years, although the majority, 107 birds, have been trapped only once. Capture rates for Brown-headed Honeyeaters by month across the entire study period are shown in Figure 1 and show a peak in late autumn. Only four birds have ever been trapped on site with well-developed brood patches (score 2 or 3 on scale of 0–3, indicating recent or current incubation)—two in October, and one each in November and December. Six birds aged as juvenile (based on plumage and soft parts) have been trapped—three in September, one in October and two in November. Average primary moult scores (sum of primary feather moult scores, ranging from 0 to 50) by month are set out in Figure 2. Primary wing moult commences in summer, but the peak of moult is in February and March.

The NMDS plot from the social network is shown in Figure 3. It shows 136 individual birds from 46 separate simultaneous trapping instances. Eighty-three birds are linked in a single cluster in the social network, with that cluster evident above the dividing line in the top right half of the figure. Dates of capture for these birds include the first and last years in the period.

Amongst the linked group, the most captures in a single calendar year was 18 individuals in 1988, followed by 16 individuals in 2005 and 13 in 2000. The largest simultaneous captures from within this group were 11 birds (March 1991, all adult birds), 10 birds (January 2000, including four birds in their first year of life) and 9 birds (October 1996, May 2006 and November 2009, in each instance including one first-year bird).

Group persistence is indicated by the long-term presence of birds in the group that were first evident in the group as juveniles. For example bird 024-54618 (upper circled point, Fig. 1) was first trapped as a first year bird in March 1996. It was retrapped seven times up to June 2003, twice in the same net as the adult bird with which it was originally trapped, 024-54619 (itself a bird trapped 7 times between 1996 and 2009; lower circled square, Fig. 3).

Geographically, the capture sites for birds within the main social group cover most of the banding site. In 2009 a foraging group was observed which included several banded birds (almost certainly part of the identified social group, as no external groups had been banded or otherwise detected on site since 1998) moving from within the banding site to beyond the western edge of the site, indicating that the home range of that resident group extended beyond the western edge at that time.

The remaining 53 birds in the NMDS plot exist as smaller discrete or poorly linked clusters (bottom left of dividing line, Fig. 3), with no links to the main social group. The latest point of capture amongst these 53 birds is May 1998. The largest simultaneous captures amongst these birds are two instances of eight birds, in May 1990 (all adults) and May 1998 (including two birds in their first year of life). The trapping months for the 53 birds outside the main cluster are spread across the year, but new captures after 1989 (covering 28 of these birds) are restricted to the months of March, April and May.

In addition to the persistent social group there have been several instances where a flock of birds has been trapped only once or twice at the study site. These show in Figure 3 as discrete clusters unconnected to the main cluster. Older birds that were resident at the start of the study have less opportunity to be revealed as members of the resident social group before dying; thus the chance of birds that were part of the actual social network existing as discrete clusters in the early years of the sample period is quite high. This is the most likely

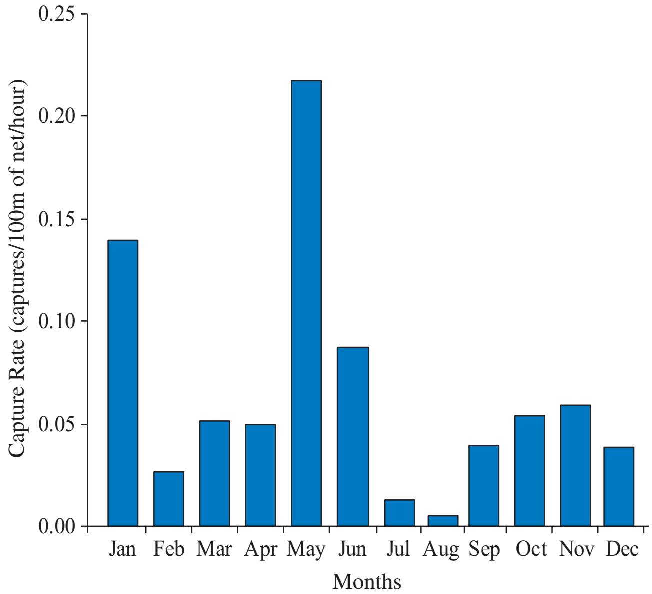

Figure 1. *Capture rates for Brown-headed Honeyeaters at Holy Camp, central western NSW, (captures per 100 m of net per hour) by month.*

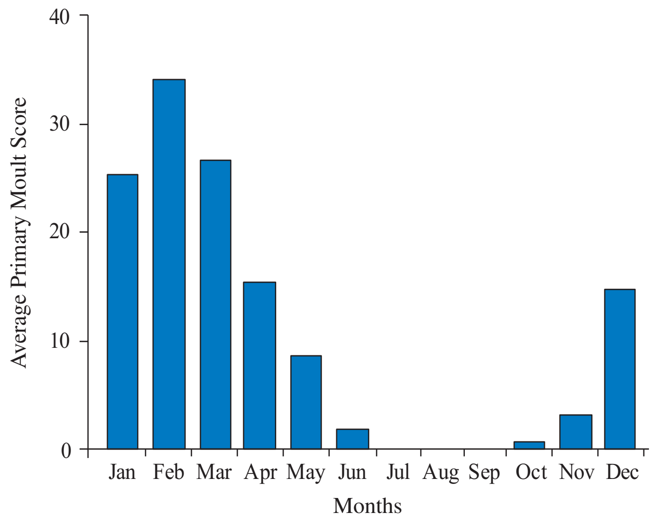

Figure 2. *Average primary moult score by month for Brown-headed Honeyeaters banded at Holy Camp, central western NSW*

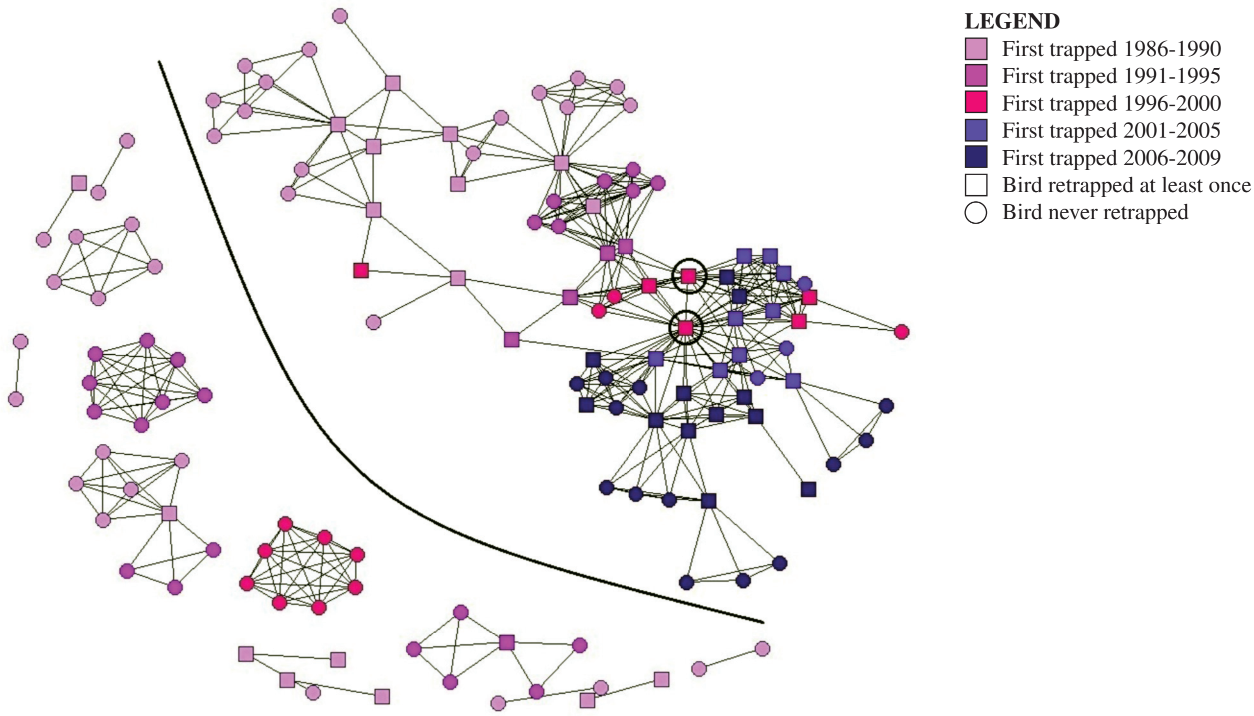

Figure 3. *Visualised social network of Brown-headed Honeyeaters over time at Holy Camp, central western NSW, as implied by simultaneous trapping events between 1986 and 2009. Each point (square or circle) in the figure is an individual bird, and each line between two points represents an instance where two birds have been trapped in the same mist net at the same time. Square points indicate birds that have been trapped more than once. Colour of the point indicates first trapping date for the bird, with lighter colours indicating earlier trapping dates. The large connected cluster in the top right half of the figure (i.e. all points above and to the right of the dividing line through the figure) indicates a single intergenerational social group that has persisted through the entire study period.*

explanation for non-linked birds that were trapped prior to about 1990. There remain several discrete clusters after this time, for which this explanation is unlikely. These birds may be from neighbouring social groups foraging or seeking water within the study site, or may be nomads from farther afield. It is difficult to distinguish between these possibilities, although the dates of capture of these isolated groups are all in autumn (May 1990, March–April 1991 and May 1998). There is a regular influx of honeyeaters to this region in autumn (Fig. 1, R. Allen pers. com.), so it is plausible that these isolated flocks are part of this movement. The autumn influx of Brown-headed Honeyeaters was not observed every year. This is consistent with Griffioen and Clarke's (2002) finding that this species is not migratory. At most, the current findings suggest infrequent nomadism for this species in this region.

DISCUSSION

The Holy Camp social network figure infers that there has been a persistent social group over the entire 24-year period, although the members of that group have changed, almost certainly due to demographic effects (births and deaths). This social group has contained at least 83 distinct birds over time. The presence of a persistent social group is consistent with the long-term site and social fidelity for this species that was suggested in Boehm's (1969) note, and is also consistent with Noske's (1983) observations of cooperative breeding for this species.

The breeding season for this species at Holy Camp appears to extend from September to December, as indicated by well-developed brood patches and presence of juveniles in these months. The late summer commencement of primary wing moult is also consistent with a breeding season that is complete by mid-summer.

The Brown-headed Honeyeaters in this study were trapped in similarly large groups at all times of year including the breeding season, suggesting that the social groups do not disaggregate into smaller groups during the breeding season. This is consistent with Noske's (1983) observations for this species around Armidale, northern NSW, but contrasts with other *Melithreptus* honeyeaters—in Tasmania, Strong-billed *Melithreptus validirostris* and Black-headed Honeyeater *M. affinis* flock sizes were significantly larger during the non-breeding season, although these two species breed colonially rather than co-operatively (Slater 1994). It also contrasts with co-operatively breeding thornbills in northern NSW (including the Buff-rumped Thornbill *Acanthiza reguloides*, which is also common at Holy Camp), where breeding pairs or small co-operatively breeding groups of 3–4 coalesced into larger territorial clans in the non-breeding season (Bell and Ford 1986).

It is interesting that this study provides no evidence of nomadic birds at the site after 1998. Given the paucity of genuine nomadic movement events identified (perhaps only three or four events), this may be a random sampling outcome. It may, however, be due to a lack of dispersing birds coinciding with regional drought conditions and consequent poor breeding outcomes, and hints that the number of nomadic birds is a function of successful breeding in good years, rather than being representative of some distinct migratory or nomadic population or a drought response.

The social network approach used in this paper has provided insights into the long-term persistence of a social group and a means for distinguishing between resident and non-resident individuals, without the need to record or track individual social interactions. Similar approaches may be useful for other flocking species, particularly where social interactions are otherwise difficult to observe (e.g. nocturnal species; migratory species).

ACKNOWLEDGEMENTS

The data set presented in this paper have been collected through the efforts of Richard Allen over many years, both in the field and in maintaining the data. Richard has been assisted by many banders and other willing helpers at Holy Camp, all of whom I thank. The concept of social network analysis was introduced to me by Terry Korodaj. Metal bird bands were supplied by Australian Bird and Bat Banding Scheme. I thank reviewers Hugh Ford and Richard Noske, both of whom provided comments which improved an earlier version of this paper.

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BANDING PROJECT REPORT No.2

Booringa Downs, Mitchell, Queensland

(Abridged version – full paper can be obtained from: www.absa.asn.au/index.php/booringa-downs)

Aim: To document long-term and seasonal changes in the composition of the avian community, longevity of individuals within a species, numbers of sedentary and migratory species, and site fidelity among migrants in a private reserve on *Booringa Downs*.

Location: 26°26.9'S; 147°49.0'E. Elevation 415 m asl. Approximately 15 km north-east of Mitchell.

Description: The study area is situated on the western edge of the Brigalow Belt Bioregion and the soils are predominantly sandy. The area is characterised by wet summers and dry winters, with a mean annual rainfall of 566 millimetres (Bureau of Meteorology). The western edge of the study site was approximately 500 metres long and bounded by a road. It extended eastwards in the shape of a truncated triangle for approximately 800 metres (Fig. 1).

The study site consisted of an undisturbed area of diverse mixed woodland comprising Cypress Pine (*Callitris columellaris*), Belah (*Casuarina cristata*), Wilga (*Geijera parviflora*), Supple Jack (*Canthium coprosmoides*), Brigalow (*Acacia harpophylla*), Poplar Box (*Eucalyptus populnea*) and Quinine Tree (*Petalostigma pubescens*) with extensive areas of Currant Bush (*Carissa ovata*) understorey as well as *Hakea* spp. and various grasses.

During 2007, all the vegetation along the road on the western side of the site, as well as a strip along the western side, was cleared for a distance of about 100 metres (see Fig. 1). In addition, the vegetation surrounding the site, as well as many of the trees in the site, was cleared and the area opened to cattle grazing.

The paddocks surrounding the site to the north and west are used solely for grazing. The area of woodland to the south, consisting predominantly of Cypress Pine, had previously been cleared and was open to grazing during the study period. The nearest permanent water lies approximately 500 metres from the north-west corner of the site, where a bore-fed dam provides water for stock. Other water courses in the vicinity of the site

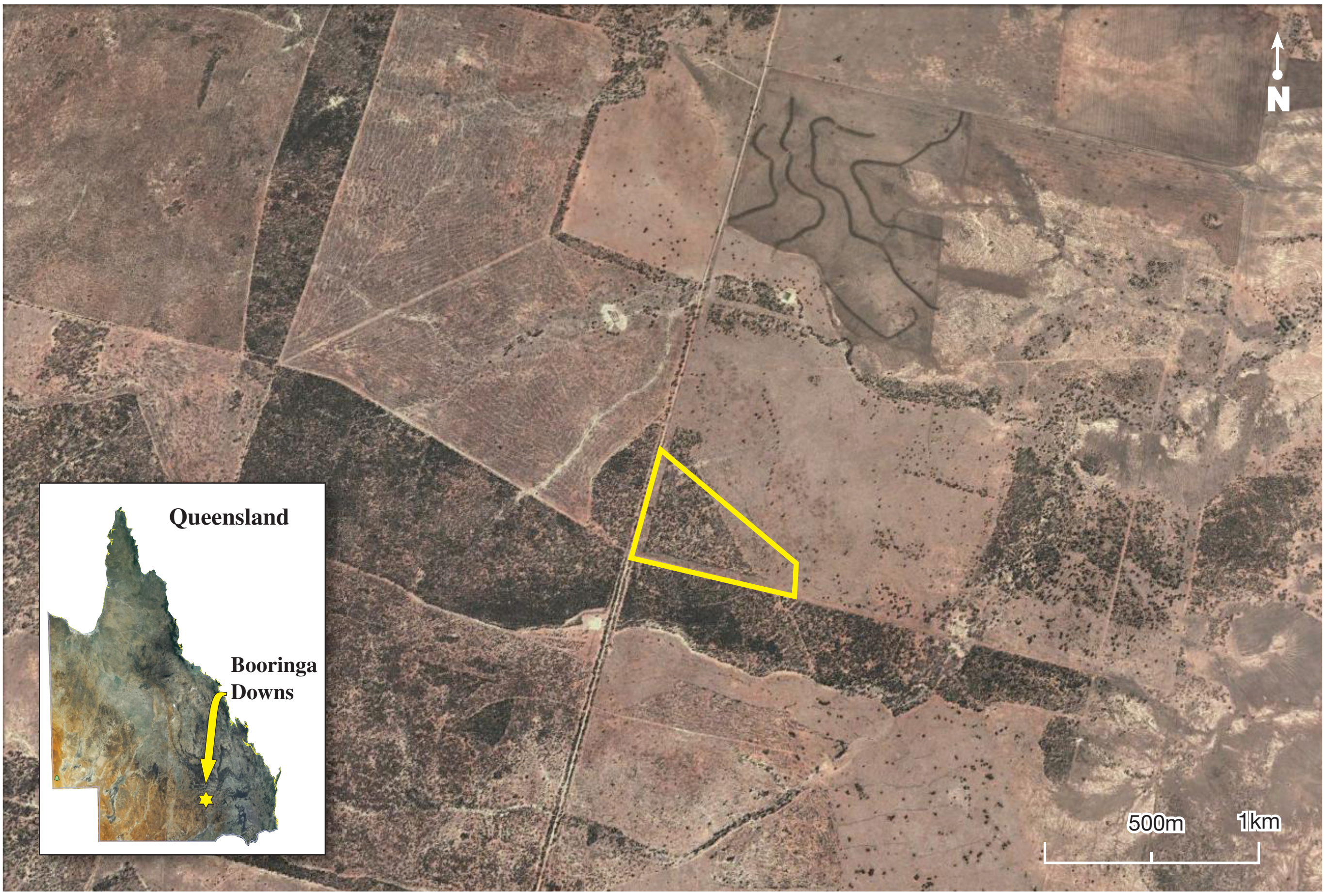

Figure 1. *Booringa Downs, Queensland* Satellite Image Courtesy of Google Earth

are ephemeral, although a small dam on the south-east corner occasionally contained water after heavy rain.

Status: This reserved area was set aside by the Allen family, owners of the *Booringa Downs*, who maintained it in an undisturbed state until 2006 when the property was sold. The site has now been converted for grazing.

Duration of Project: June 1990 – June 2007.

METHODS

Scientific names of species follow that of Christidis and Boles (2008).

Banding was carried out during 24 periods: 10 in summer, 7 in autumn, 5 in winter and 2 in spring. Banding days within each period averaged five (range 3–5) with a total number of 119 days for the whole study. The banding days in each period were run consecutively.

Twelve nets were erected in random positions within the site each day – 10 nets were 31 millimetres mesh (total length 113 m) and 2 (total length 21 m) were 25 millimetres mesh. The total length of 134 metres was erected each day and nets were raised to a height of 2.7 metres. They were opened from just before sunrise until sunset and were continuously monitored. Nets were open for a total of 1547 hours for the whole study.

So that comparisons could be drawn between banding periods, each period was counted as a single datum point. The total number of birds banded for each species trapped during each period was tallied and tabulated – bird retrapped during the period in which they were banded were not counted. Capture rates for each species were calculated as: *Number of birds caught per number of hours nets were open per 100 metres of net erected (x10)*. The multiplication factor was added so that calculated numbers could be displayed to one decimal point.

To calculate the retrap percentage for each species the number of retrapped birds was divided by the total number trapped and displayed as a percentage – a retrapped bird was only counted once irrespective of the number of times it was trapped.

Birds were banded using bands supplied by the Australian Bird and Bat Banding Scheme and morphometric details (tail, tarsus and wing lengths; weight) were also recorded for each bird.

RESULTS AND DISCUSSION

A total of 1862 individuals representing 82 species was captured and banded during the study period. The overall capture rates varied from a maximum in December–January 1990–91 (24.5) to a minimum in September–October 2002 of just 1.5.

The avian community at the study site could be divided into three broad components: the resident species, seasonally occurring species (migrants), and those that occurred irregularly (nomads). The Silvereye *Zosterops lateralis* was the most commonly trapped species, followed by the Double-barred Finch *Taeniopygia bichenovii* and Spiny-cheeked Honeyeater *Acanthagenys rufogularis*. However, the Variegated Fairy-wren *Malurus lamberti*, Rufous Whistler *Pachycephala rufiventris*, Speckled Warbler *Chthonicola sagittata* and Splendid Fairy-Wren *Malurus splendens* were the most frequently encountered species. Migrant species such as Black-eared Cuckoo *Chalcites osculans*, Horsfield's Bronze-Cuckoo *Chalcites basalis* and Rainbow Bee-eater *Merops ornatus* were present mainly between September and April, although it is noteworthy that Horsfield's Bronze-Cuckoo, Shining Bronze-Cuckoo *Chalcites lucidus*, Pallid Cuckoo *Cacomantis pallidus* and Fan-tailed Cuckoo *Cacomantis flabelliformis* were also captured during June. The last-named group comprised mainly more western irruptive species, such as the Diamond Dove *Geopelia cuneata*, Budgerigar *Melopsittacus undulatus*, Black Honeyeater *Sugomel niger*, Crimson Chat *Epthianura tricolor* and Zebra Finch *Taeniopygia guttata*, and they were relatively infrequent. These irruptions coincided with low rainfall in the study area, which may mean that they were a result of drought to the west.

The proportion of individual species that comprised the resident trapped population varied considerably over time but when averaged over the 24 banding periods the insectivores (principally the fairy-wrens (19.4%); thornbills, Weebill *Smicrornis brevirostris* and Speckled Warbler (14.5%); robins and Rufous Whistler (6.2%)) and honeyeaters (32.6%) constituted the largest groups with the granivores at 9.8 percent.

Longevity

The total re-trap percentage for all birds was 10.4 percent, counting only those birds that were retrapped during a following visit. Some resident species, particularly among the Maluridae, were re-trapped up to five times.

Maximum recorded ages after banding of all retrapped species were recorded. The oldest being an Inland Thornbill *Acanthiza apicalis* 12+ years, followed by a Rufous Whistler 9+, Brown-headed Honeyeater *Melithreptus brevirostris* 9+, Splendid Fairy-Wren 8+, Chestnut-rumped Thornbill *Acanthiza uropygialis* 8+, Bar-shouldered Dove *Geopelia humeralis* 7+, Australian Owlet-Nightjar *Aegotheles cristatus* 7+ and Noisy Miner *Manorina melanocephala* 7+.

Changes over the study period

Although there were considerable annual and seasonal fluctuations in the species composition of the avifauna during the 18-year study period, the most obvious trend was an overall reduction in both numbers and diversity. The lowest numbers and diversity recorded in 2007 may have been due to anthropogenic disturbance and habitat alteration, but prior to this, the area was relatively undisturbed.

Bureau of Meteorology rainfall records for Mitchell indicate that total rainfall and distribution of rainfall are highly variable. These patterns, when compared to bird numbers are suggestive of a possible correlation, but further analyses at a species level would be required to establish this. Rainfall has certainly been proposed as a factor influencing seasonal movements of honeyeaters (Keast 1968, 1984) and the nomadism of many Australian arid zone species relates to good breeding in wet years and subsequent dispersal (Nix 1976; Newton 2008).

Species capture rates

The Superb *Malurus cyaneus*, Variegated and Splendid Fairy-wren varied in abundance over time, although, the Superb Fairy-wren was generally less abundant than the other two species.

Spiny-cheeked Honeyeaters, one of the more abundant species, were almost entirely absent from April to July. A similar pattern, although not as marked, was observed for Striped *Plectorhyncha lanceolata*, Brown *Lichmera indistincta* and Brown-headed Honeyeaters.

The Yellow, Yellow-rumped and Chestnut-rumped Thornbill's overall capture rates were comparable (3.7, 3.6 and 3.2 respectively) while the Inland Thornbill's overall capture rate (5.0) was higher. Its proportion, across the study, remained relatively constant when compared with the other thornbills whose capture rates fluctuated more widely.

The Speckled Warbler was present throughout the study period with no apparent seasonality. Other common species (e.g., Rufous Whistler and Noisy Miner) also formed a relatively consistent proportion of the resident community. Similarly the granivorous Double-barred Finch was common throughout the study period, although usually more abundant in December–January. Many of the insectivorous species (e.g., the robins and flycatchers) were more abundant in the first half of the study.

ACKNOWLEDGEMENTS

This project is dedicated to the memory of the late Mrs Dawn Allen who set up the nature reserve within Booringa Downs. The work would not have begun without her enthusiasm for birds. Her support for the project, her many kindnesses throughout the years, and subsequently of her son Michael Allen, enabled the project to continue for 18 years. The ABBBS supplied bands to S.J.M. Blaber (A1146) and the project was carried out under Qld EPA Scientific Purposes Permit WISP01199403 and Qld DEEDI ethics permit CA2008/11/317. We are grateful to Ian Macleod of CSIRO for extraction of BOM rainfall data and to Dr John Farrell for all his help with the manuscript.

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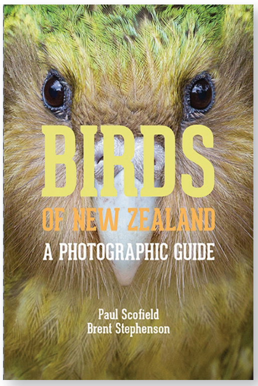
Book Review



Birds of New Zealand
a Photographic Guide

Paul Scofield and Brent Stephenson. 2013. Yale University Press. Paperback, 1000 coloured photographs, maps. 544 pp. ISBN 9781869407339. RRP $60.

Any 'birdo' understands that a visit to a foreign country necessitates research into its birdlife and obtaining a good field guide. The avifauna of New Zealand is represented by one of the most diverse seabird assemblages in the world, whilst some of the terrestrial species are highly unique and are now known to have ancient pedigrees central to the evolution of some of the world's largest bird orders. In *Birds of New Zealand a Photographic Guide*, Paul Scofield and Brent Stephenson provide not only a means of identification of the 365 bird species that have been recorded in New Zealand, but have endeavoured to give the reader an insight into the biology and pedigree of New Zealand birds which together make them such a fascinating collection of species.

Both authors are well qualified for such an undertaking. Paul Scofield is the senior curator of natural history at Canterbury Museum and specialises in the evolutionary history and taxonomy of Australasian birds. He also studies pelagic species and was part of a team that rediscovered the Kermadec Petrel in 1988. Brent Stephenson also has an academic background but has been running his own bird tour company since 2003. Like Scofield, he has considerable expertise in pelagic species, and not to be outdone by his co-author, was jointly responsible for the 2003 rediscovery of the New Zealand Storm Petrel. Stephenson is also an accomplished photographer and the book is furnished largely with his own images.

Birds of New Zealand has a layout typical for a modern bird guide with a standard introductory sequence followed by individual species accounts. In line with the move amongst modern guides to utilise taxonomic sequences that assimilate recent molecular evidence, the species accounts are arranged a little differently from older, traditional sequences. However, at the ordinal level at least, the most substantial changes incorporated in other works are not present here, and so those familiar with the older sequences should have little trouble navigating their way around the book.

The species accounts provide sections on identification and separation from similar species, and cover in good detail the different races and subspecies that may be encountered. Combined with the vocalisations section, and quite a thorough biometric section, there is ample information to allow for identification of species even before the photos are considered. In this regard each species account is accompanied by not one but several photos, covering several of the pertinent diagnostic features. Few photographic guides of this format are as well furnished with images, and this is all the more commendable given they are generally of good to very high quality, and complement the text very well.

Distributions are covered in detail in text, and also by maps which are simple but very effective. Unfortunately habitat information can be a little sparse and is usually provided in the introductory information for each species, although in the New Zealand context this is possibly less critical for identification compared to the Australian situation, where there is more fine separation based on a greater diversity of vegetation classes.

One of the main features that sets this book apart as a guide is the information on taxonomy. All orders and families covered in the book have short notes outlining their relationships before the relevant species descriptions. Furthermore, within the descriptions themselves there is a taxonomy section that describes the relationships of individual species, and also provides background to decisions regarding a taxon's status as species, subspecies, etc. Uniquely, and within the same section, there is also a detailed etymology regarding Maori, English, and Latin names. For a visiting bird enthusiast these notes on taxonomy identify the most unique families and species. For an Australian visitor it also informs on the relationships between New Zealand and Australian species which would surely be a great advantage in planning any trip to the 'Shaky Isles'.

Considered as a potential field guide, the book would already be large for a work covering 365 species and the book is almost identical in size and weight to Pizzey and Knight's Field Guide to the Birds of Australia. As such it is still portable, but if weight and size are an issue there are more compact guides available like Heather and Robertson's *Field Guide to the Birds of New Zealand*. This is an illustrated guide that comes in a compact hand guide format, as well as a larger format of similar size to the Scofield and Stephenson guide but furnished with more extensive notes on species biology and behaviour. However, where the Scofield and Stephenson book differentiates itself in any comparison is the up-to-date taxonomic information, photography, and detailed descriptions of the pelagic species for which New Zealand is renowned. It is also worth noting that a separate interactive *Birds of New Zealand* app is available that incorporates vocalisations and smart-search functionality. It is perhaps no coincidence given Stephenson's guiding background that these features, among others, mean this book is very well tailored to the needs of any visiting bird enthusiast.

Birds of New Zealand a Photographic Guide is overall a well constructed work that combines the attributes of a very good field guide with up-to-date reference information. It is an attractive book that in my opinion must be considered as possibly the finest photographic guide ever produced on New Zealand birds and a 'must read' for any Australian bird enthusiast contemplating a trip 'across the ditch'.

Dion Pou
Seven Hills, NSW

Obituary

Henry John de Suffren Disney (1919–2014)

Photo: Peter Fullagar

When John Disney was appointed Curator of Birds at the Australian Museum it marked the first time since the death of A.J. North in 1919 that the Museum had a person exclusively occupying the position of Curator of Birds.

While in England, John had collected in north Finland and Newfoundland, before serving as a photographer with the Royal Air Force during World War II. Following his education at Cambridge, he spent time in Africa from 1946 first at the Kaffarian Museum, South Africa, then as a cotton entomologist in Tanganyika Territory (now Tanzania), East Africa. From 1953, John spent ten years as an applied biologist studying the biology of species that damaged crops and other food sources and working out methods of control. He eventually worked with the small finch, the Red-billed Quelea, the world's most abundant wild bird species. It nested communally in flocks of tens of thousands to millions, which could quickly devastate a field of grain.

Working with the famous zoologist Jock Marshall, John investigated the birds' annual cycle based on plumage and gonad development in the laboratory, while conducting active management of breeding colonies (frequently involving explosives and flame throwers). It was this work that stimulated his interest in identifying criteria to determine ages and sexes of birds. It was upon the recommendation of Marshall that the Museum hired John directly from Africa, sight unseen.

Soon after taking up the position in 1962, John began working with the local bird-banding community, joining them on banding trips as he began to learn the Australian birds. He was involved with the Australian Bird Banders' Association from its founding, serving from the start as Assistant Editor (1962–1974) and being elected as its third President (1966–67) and later as Vice-President (1974–76). When this organisation evolved into the Australian Bird Study Association in 1977, he was elected as its first president. He was a member of the committee for a number of years (1981–88).

John realised that many common Australian birds, mainly passerines, lacked detailed information on their sequence of plumage changes and sexual differences. He also recognised that existing collections contained too few specimens that had been properly sexed at the time of preparation or had breeding condition, soft part colours, and moult recorded. He started a research program to identify age and sex criteria in Australian birds. This involved acquiring suitable specimens to fill these gaps and building series of birds from different times of year. Many newly prepared skins had a wing removed and spread. These were invaluable for John's work on moult, as was examination of body moult, cranial pneumatisation and cloacal protuberances.

In the initial years, this involved many short, repeated field trips to a few select locations to obtain species throughout their annual cycles. He enjoyed fieldwork and displaying his bush craft, and was rather set in some of his routines. Notably, he was exacting when it came to making the morning porridge. John had made a double boiler billy that allowed the porridge to cook while he spent the first hour searching for birds.

Among the important curatorial practices John introduced, the most important was recording of additional biological information for incoming specimens. He rightly regarded the basic specimen data routinely collected until that time as inadequate for life history studies. Biological information (measurements, gonad condition, moult, soft part colours, pneumatisation) were captured on datasheets that he introduced and completed for each bird before being prepared.

Using criteria based on these "calibrated" series of skins, John published a series of papers in *Australian Bird Bander* and later *Corella* under the general title *Bird in the Hand*. Those published up to 1974 were reissued as a bound volume, under that title and the editorship of Bill Lane, to appear in time for the International Ornithological Congress, held that year in Canberra.

John noted that plantations of introduced Radiata Pine were good habitat to find Flame Robins, one of his target species. He combined collecting trips to these forests with surveys of the native birds encountered. His paper with Anthony Stokes was the first to document bird use of this monoculture in Australia.

Starting in 1969, John and co-workers began a program to locate and survey the endangered Lord Howe Island Woodhen. They discovered that fewer than 30 birds remained. Part of the monitoring involved banding as many individuals as possible and working out aging and sexing criteria. Their subsequent recommendations led to a captive breeding program and an eradication program for feral animals affecting the Woodhen and its habitat. The Woodhen now occurs in many lowland areas from which it had been extirpated.

When observations in the early 1970s confirmed the presence of the Eyrean Grasswren, known from only three specimens collected in 1874, the recently formed National Photographic Index of Birds decided to obtain photographs, as none existed at that time. In conjunction with members of the Index, John led a party to the eastern edge of the Simpson Desert. These birds were discovered farther west along the South Australian-Queensland border and the first photographs obtained.

When John retired from the Museum in late 1979, he was appointed as a Research Associate. He continued his studies of age and sex variation, incorporating the examination of captive birds at Taronga Zoo with his work on Museum specimens, and published several papers. He retained an interest in these topics, even after he had ceased actively studying them himself.

Walter Boles,
The Australian Museum, Sydney

RECOVERY ROUND-UP

This section is prepared with the co-operation of the Secretary, Australian Bird and Bat Banding Schemes, Australian Nature Conservation Agency. The recoveries are only a selection of the thousands received each year; they are not a complete list and should not be analysed in full or part without prior consent of the banders concerned. Longevity and distance records refer to the ABBBS unless otherwise stated. The distance is the shortest distance in kilometres along the direct line joining the place of banding and recovery; the compass direction refers to the same direct line. (There is no implication regarding the distance flown or the route followed by the bird). Where available ABBBS age codes have been included in the banding data.

Recovery or longevity items may be submitted directly to me whereupon their merits for inclusion will be considered.

Hon. Editor

The following abbreviation appears in this issue:

AWSG - Australasian Wader Study Group.
VWSG - Victorian Wader Study Group.

Lord Howe Woodhen *Gallirallus sylvestris*

100-90073. Immature (1) banded by R.H. Harden on Lord Howe Island, NSW on 1 Nov. 1991. Recovered dead near banding place on 27 Nov. 2007, over 15 years after banding.

(This is the oldest recorded for the species.)

Tasmanian Native-hen *Tribonyx mortierii*

121-34269. Juvenile (J) female banded by A.W. Goldizen at Darlington, Maria Island, Tas. on 19 Nov. 1996. Recovered dead near banding place on 17 April 2008, over 11 years, 4 months after banding.

(This is the oldest recorded for the species.)

Australian Pied Oystercatcher *Haematopus longirostris*

100-85114. Adult (2+) banded by VWSG at Inverloch, Andersons Inlet – Point Smythe, Vic. on 15 May 1988. Recaptured, released alive with band on the Shores of 80 Mile Beach, WA by AWSG on 11 Aug. 2013, over 25 years, 2 months after banding. 3187 km NW.

(This is the longest recorded movement for the species.)

Sooty Oystercatcher *Haematopus fuliginosus*

(a) 100-96944. Nestling banded by VWSG at The Nobbies west end of Phillip Island, Vic. on 31 Jan. 1991. Recovered dead at Scotchmans Nature Reserve near Summerland Beach, Phillip Island, Vic. on 21 Dec 2010, over 19 years, 10 months after banding.

(This is the oldest recorded for the species.)

(b) 101-21273. Adult (3) banded by VWSG at Lyons Downs, Yanakie, Vic. on 12 June 2002. Readable band/flag sighted in field, number of standard band inferred at Nora Creina, SA on 10 July 2007. 585 km W.

(This is the longest movement recorded for the species.)

Black-winged Stilt *Himantopus himantopus*

(a) 071-53320. Adult (2+) banded by AWSG at Beaches Crab Creek Road, Roebuck Bay, Broome, WA on 18 Aug. 1982. Recaptured, released alive with band at banding place on the 13 Aug. 1998, over 15 years, 11 months after banding.

(This is the oldest recorded for the species.)

(b) 073-58552. Adult (2+) banded by AWSG at Taylors Lagoon, 70 km East of Broome, WA on 10 Dec. 2009. Readable band/flag sighted in field, number of standard band inferred at Thompson Lake, WA, on 1 Nov. 2010. 1746 km S.

(This is the longest movement recorded for the species.)

Lesser Sand Plover *Charadrius mongolus*

041-70537. Adult (2+) banded by AWSG at Beaches Crab Creek Road, Roebuck Bay, Broome, WA on 31 Mar. 1994. Recaptured, released alive with band at banding place twice, the last occasion on 15 Nov. 2009, over 15 years, 7 months after banding.

(This is the oldest recorded for the species.)

Greater Sand Plover *Charadrius leschenaultii*

051-27980. Adult (2+) banded by AWSG at Beaches Crab Creek Road, Roebuck Bay, Broome, WA on 17 Apr. 1985. Recaptured, released alive with band at banding place on 7 Nov. 2007, over 21 years, 6 months after banding

(This is the oldest recorded for the species.)

Hooded Plover *Thinornis rubricollis*

051-57984. Adult (1+) banded by M.A. Weston at Barwon Heads, Vic. on 17 Oct. 1996. Recaptured, released alive with band at banding place on 10 Dec. 2012, over 16 years, 1 month after banding.

(This is the oldest recorded for the species.)

Black-tailed Godwit *Limosa limosa*

071-85094. Adult (2+) banded by AWSG on the shores of 80 Mile Beach, WA on 29 March 1988. Recaptured, released alive with band at Beaches Crab Creek Road, Roebuck Bay, Broome, WA on 21 Nov. 1999, over 11 years, 7 months after banding.

(This is the oldest recorded for the species.)

Red Knot *Calidris canutus*

052-50051. Immature (1) banded by VWSG off Manns Beach, Corner Inlet, Vic. ($38^0$41'S $146^0$50'E) on 22 Feb. 2007. Two overseas recoveries;

(1) Recaptured, released alive with band east of Meinypilgyno Village, Chukotka, Russia, on 25 May 2012, 11 574 km NNE.

(2) Readable band/flag sighted in field, number of standard band inferred at Meinypilgyno, Chukotka, Russia, ($62^0$33’14”N $177^0$05'42"E) on 27 May 2013, over 6 years, 3 months after banding. 11 575 km NNE.

Red-necked Stint *Calidris ruficollis*

033-67143. Immature (1) banded by VWSG at Werribee Sewerage Farm, Vic. On 31 Dec 1988. Recaptured, released alive with band at Beaches Crab Creek Road, Roebuck Bay Broome, WA by AWSG on 27 Oct. 2010, over 21 years, 9 months after banding.

(This is the oldest recorded for the species.)

Brown Treecreeper *Climacteris picumnus*

042-19622. Adult (2+) female banded by G. Fry at Warraderry State Forest, near Grenfell, NSW on 20 Mar. 2009. Recaptured, released alive with band at banding place by A. & A. Leishman on 4 Jun. 2014, over 5 years 2 months after banding.

Eastern Yellow Robin *Eopsaltria australis*

025-97524. Adult (1+) male banded by A. & A. Leishman at Camden Airport, NSW on 30 July 2007. Recaptured, released alive with band at banding place five times, the last occasion on 19 April 2014, over 6 years, 8 months after banding.

025-97063. Adult (2+) female banded by G. Fry at Warraderry State Forest, near Grenfell, NSW on 26 Jul. 2005. Recaptured, released alive with band at banding place by A. & A.Leishman on 4 Jun. 2014, over 8 years 11 months after banding.

Notice to Contributors

Manuscripts relating to any form of avian research will be considered for publication. Field studies are preferred particularly where identification of individual birds, as by banding, has formed an integral part of the study. Some broad areas of research which do not necessarily require individual identification include morphometric analyses, techniques, species diversity and density studies as well as behavioural investigations. Behavioural, plumage and breeding studies can be conducted in captivity but must provide basic ornithological knowledge rather than avicultural interest.

Manuscripts are classified as either major articles (more than 1,500 words) or minor articles (500 to 1,500 words). Minorarticles need no summary. Shorter notes relating to almost any aspect of ornithology are welcomed but must adhere to the aims of the Association. Species lists or sightings which are not discussed in relation to historical evidence or scientific parameters are not suitable for publication in *Corella.* Authors proposing to prepare Seabird Island items should contact the Assistant Editor,Seabird Islands, and obtain a copy of the guidelines.

The copyright of material published in *Corella* is assigned to the Australian Bird Study Association.

Contributors are requested to observe the following points when submitting articles and notes for publication in *Corella*.

Manuscripts:

A guide to the format required for tables, figures and manuscripts can be attained by reference to a recent edition of the journal and more specifically to the Publication Style found on the ABSA website.

Articles or notes should be sent via email to the editor as a .doc or .rtf file or typewritten and submitted in triplicate via post. Double spacing is required with typing on one side of the paper only. Margins of not less than 25 mm width at the left hand side and top, with similar or slightly smaller at the right hand side of the page are required.

All pages of the manuscript must be numbered consecutively, including those containing references, tables and captions to illustrations, the latter placed in after the text. No underlining and no abbreviations should be used within the text.

The *Style Manual for Authors,Editors and Printers* (6th edition 2002; John Wiley & Sons Australia, Ltd.) is the guide for this journal. Spelling generally follows the Macquarie Dictionary.

Nomenclature and Classifications follow:

Christidis, L. and Boles, W. E. (2008). 'Systematics and Taxonomy of Australian Birds'. (CSIRO: Collingwood, Victoria).

Proper nouns, particularly place and bird names must commence with a capital letter.

Headings are as follows: **HEADING – capitals and bold** (e.g. **RESULTS**)
Sub Heading – lower case and italics (e.g. *Ecology*)

Referencing:

References to other articles should be shown in the text – '. . . Bell and Ferrier (1985) stated that . . .'or '…. this is consistent with other studies (Jones 1983; Bell and Ferrier 1985).'– and in the Reference Section as:

Bell, H. L. and Ferrier, S. (1985). The reliability of estimates of density from transect counts. *Corella* 9: 3-13.

Jones, J. C. (1983). 'Sampling Techniques in Ornithology.'(Surrey Beatty and Sons: Chipping Norton, NSW.)

Figures (Maps and Graphs) and Tables:

The printable area of the page is 18 cm x 27 cm; double column figures/tables will be 18 cm across; single column figures/ tables will be 8.5 cm across; widths between one column and double column can also be accommodated.

The captions for figures should be typed up onto a page separate from the figure.

Maps

Maps should be clear and relevant to the study and can be submitted in a variety of formats (.tif, .eps, .pcx) but there commended one is a high resolution .jpg file (colour is acceptable). In some instances simply listing the latitude and longitude may suffice instead of a published map. Maps should only show necessary information. Excessive labelling(including names of towns, roads, rivers) will clutter the figure making it difficult to locate key place names. Photocopies of original hand drawn maps are not suitable for publication. They should be submitted only initially. When the paper is accepted for publication, the originals must be submitted so that they can be scanned into an appropriate electronic format.

Graphs

Lines should be thick and dark and any fill used should show a clear distinction between sets of data (colour fills are acceptable). Borders around the graph and the key are not necessary. The recommended format is an .xls file – this makes it very easy to adjust fills, thickness of lines etc, if necessary.

Where possible, please present the figure at final size. Figures that seem satisfactory when they are large, can present problems when they are reduced. Remember that if the figure has to be reduced for publication the figure will reduce equally in all dimensions i.e. both width and height will reduce. This can cause some problems, such as: (i) Line graphs where the lines are very close together can lose clarity. (ii) The typeface will reduce. Please ensure that the final typeface size AFTER reduction will be a minimum of 10 times Times New Roman typeface.

Tables

The recommended format is an .xls file but tables created in Word are acceptable. These should normally have a maximum size of one page but larger tables can be accommodated, if necessary.

FOR MORE DETAILED INFORMATION OR ASSISTANCE IN THE PREPARATION OF FIGURES PLEASE CONTACT THE PRODUCTION EDITOR.

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