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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 & 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 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.

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 4 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.

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 h in early morning or late afternoon), there was no activity or evidence of use. The 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 3). 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 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 ~800 pairs in NSW is located on the coast (Debus 2008; see Appendix 2). As predicted by O'Donnell & 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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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

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 ~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 ~600 pairs on ~1200 km 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 2 km 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 ~50 known pairs and potentially double that number in East Gippsland alone, and only 1–1.5 km between some pairs (Bluff and Bedford 2011), or perhaps 200 pairs in Victoria overall. The SPRAT estimate (www.environment.gov.au/sprat) of >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 ~40 pairs in two small sample areas of the Northern Territory, and 1–6.5 km 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.

Figure 1. *White-bellied Sea-Eagles' nest on artificial pole and platform, Bunnings carpark, Townsville, June 2008. Photo: George Baker*

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

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

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