Ravens are a key threat to beach-nesting birds

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Summary. Depredation of nests by native and introduced predators is contributing to the decline of beach-nesting shorebirds in many parts of Australia. Determining the relative importance of these predators is crucial for designing and implementing appropriate management strategies for shorebird conservation. We deployed and monitored 82 artificial Red-capped Plover Charadrius ruficapillus nests, on six beaches within a 140-km stretch of the New South Wales Lower North Coast, to identify the main predators of beach-nesting shorebird nests and their relative importance. After 18 days, 53 (63%) artificial nests were depredated. Australian Ravens Corvus coronoides and Forest Ravens C. tasmanicus were the chief nest-predators, and were responsible for depredating 40 (49%) nests collectively. Comparatively few nests were depredated by European Red Foxes Vulpes vulpes, which depredated 8 (10%) nests. The rate of depredation (nests depredated/2 days) by ravens was greater than the rate of depredation by foxes (P < 0.05). Other predators preyed upon 5 (5%) nests.

Introduction

Nest-depredation is a major factor contributing to the decrease in populations of resident, beach-nesting shorebirds in many parts of Australia (Tomkovich & Weston 2007). A variety of nest-predators, both native and introduced, forage on Australian beaches (Rose 2001; Tomkovich & Weston 2007) and, in many areas, the abundance and diversity of predators have been elevated by human-mediated environmental change, and human disturbance has increased the vulnerability of shorebird nests to these predators (Recher & Serventy 1991; Coulson & Coulson 1998; Weston & Elgar 2007).

Introduced European Red Foxes Vulpes vulpes are reputed to be proficient nest-raiders and are suspected to account for 17–27% of shorebird nest losses (Weston 2003), although, in one study, foxes may have accounted for up to 36% of depredations of artificial Hooded Plover Thinornis rubricollis nests (Maguire et al. 2009). Accordingly, in mainland Australia, most predation-mitigation measures at shorebird nesting areas are directed towards foxes, with intensive 1080 baiting campaigns during the nesting season (Mahon 2009).

Land managers rarely implement measures to control avian predators (Dunn & Harris 2009; Harris & Dunn 2010) because protective legislation for native
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species often restricts the use of lethal control for native, but overabundant, avian predators. Despite intensive fox control, however, the incidence of nest-failure remains high at many shorebird nesting sites (Weston 2003; Dunn & Harris 2009; Harris & Dunn 2010). One possible explanation is that the importance of predators other than foxes has been underestimated.

Understanding the relative impacts of co-occurring predators of nests to shorebird recruitment is crucial for determining resource allocation for predator control at breeding sites and for designing and implementing appropriate management strategies for shorebird conservation. To identify the main predators of beach-nesting shorebird nests and their relative importance within the shorebird nest-predator guild, we deployed and monitored artificial Red-capped Plover *Charadrius ruficapillus* nests on six beaches within a 140-km stretch of the New South Wales (NSW) Lower North Coast.

**Study area and methods**

**Study area**

Within the 140-km stretch of the NSW Lower North Coast between Newcastle and the Manning River, we deployed artificial Red-capped Plover nests on six beaches: 22 at Stockton, 15 at Lemontree, 15 at Mungo, 6 at Lighthouse, 10 at Seven Mile and 14 at Nine Mile (Figure 1). These beaches are largely undeveloped, high-energy surf beaches with intact dune systems and are administered by the NSW Office of Environment and Heritage within the Worimi State Conservation Area, Myall Lakes and Booti Booti National Parks and Darawank Nature Reserve. Camping is permitted on parts of Stockton Beach, vehicular access is permitted on all beaches except Seven Mile and, before the present study, national park

![Map of the study area on the Lower North Coast of NSW. Teardrop-shaped icons indicate beaches where artificial Red-capped Plover nests were placed. Pin-shaped icons indicate major urban centres. Image from Google Earth.](image)
rangers had deployed 1080 baits for foxes or Dingoes *Canis dingo* on or near all beaches except Mungo and Lighthouse. Red-capped Plovers and Pied Oystercatchers *Haematopus longirostris* nest on beaches in the study area, but are subject to high levels of predation and human disturbance (B. Cann & T. DeMamiel pers. comm.).

**Artificial nests**

We deployed and monitored artificial nests in order to provide proxies for depredation rates of real shorebird nests. We used artificial nests because of the logistical difficulties involved in locating a large sample of natural nests and to avoid disturbing real nests of the legally protected study species.

We constructed artificial nests to resemble nests of the Red-capped Plover, which commonly breeds in the study area, and deployed them in October and November 2010 to coincide with the nesting season of this species. Eggs of the Japanese Quail *Coturnix japonica* were used because they are similar in size, shape and coloration to Red-capped Plover eggs [Japanese Quail: 34 × 27 mm (Kumari *et al.* 2008); Red-capped Plover: 31 × 23 mm (Marchant & Higgins 1993)]. Although humans could not detect odour from artificial nests, the eggs likely retained some bird odour because these were obtained fresh, unwashed, from a quail farm and placed in the field within 12 hours.

In the study area, pairs of Red-capped Plovers typically nest separately (Marchant & Higgins 1993). The artificial nests were spaced ~400 m apart, which was the closest distance observed between natural nests. The selected nest-sites appeared to be typical of those of breeding birds, in open habitat, including on shell middens, amongst scattered charcoal or small stones, or ground-layer vegetation in the dunes, often close to ephemeral wetlands (Marchant & Higgins 1993). Before placing each nest, the surroundings were scanned with binoculars (Nikon Monarch 10 × 42), and if ravens were observed we did not place an artificial nest and moved on. At each nest-site, we made a shallow scrape (10 cm diameter, ~1.3 cm deep: see Marchant & Higgins 1993) into which we placed two eggs. The substrate under, and surrounding, all of the artificial Plover nests was pre-existing, fine, white beach sand. The location of each nest-site was recorded using a Global Positioning System (Garmin GPS 60, USA).

The incubation period of the Red-capped Plover is ~30 days (Marchant & Higgins 1993). Because few nests were depredated after the first 10 days, we ran the study for 18 days. Because of the high number of nests and the distances between them, we grouped beaches in the south (Stockton, Lemontree and Mungo) and north (Lighthouse, Seven Mile and Nine Mile), and checked nests in each group on alternate days. A nest was considered depredated if one or both eggs was missing or damaged. Depredated eggs were not replaced as we were interested only in the first take at a site, but after 8 days we replaced any remaining eggs with fresh eggs before the remaining eggs sun-bleached or spoiled.

**Identification of predators**

Because of favourable weather, regular nest checks and a fine sand substrate, we were able to use tracks in the sand surrounding artificial nests and observations of nest damage to infer a predator at all depredated nests. Ravens typically removed both eggs, though sometimes tiny shell fragments were found beside raven tracks. Fox and dingo predation was characterised by partial cracking of the eggshell (Maguire *et al.* 2009) and the nest was often pawed and dug. Although we were unable to distinguish between domestic dog and dingo tracks, Mungo Beach was the only location where tracks indicated that artificial Red-capped Plover nests had been depredated by dingoes or dogs; because of this beach’s
isolation, frequent visitation by dingoes and being off-limits for domestic dogs, we assumed that dingoes were the predators of those artificial nests.

The Australian Raven *Corvus coronoides* and Forest Raven *C. tasmanicus* are sympatric in the study area, where the former is ubiquitous and the latter is rarer in the south (JDR pers. obs.). We regularly observed both species foraging in the dunes and witnessed an Australian Raven swallowing eggs from an artificial Red-capped Plover nest. Because their tracks are difficult to distinguish, we considered the two raven species collectively. In most cases, tracks could be identified by their large size, long stride and long hind-toe drags, but Australian Magpies *Cracticus tibicen* and Pied Currawongs *Strepera graculina* were also present in the study area and could have been responsible for some of the nest-depredation that we ascribed to ravens.

**Analysis**

We performed all analyses in SPSS version 22. Because we were interested in depredation effects, we omitted from all analyses two nests that were destroyed by human activity. Because of the presence of right-censored points in the dataset, we used the non-parametric Kaplan-Meier procedure to calculate survival functions for artificial nests for the experimental period, grouped by beach. We then compared survival functions among beaches using Log Rank (Mantel–Cox), Breslow (Generalized Wilcoxon) and Tarone–Ware tests. We compared the mean number of days before first take for all nests depredated by ravens and all nests depredated by foxes using an independent-samples *t*-test. We used analysis of covariance (ANCOVA) to test if there was a difference in the number of nests depredated by ravens and the number of nests depredated by foxes for each 2 days of the experimental period. Before the ANCOVA, we tested that the *y*-values were normally distributed using Shapiro–Wilk tests, then square-root transformed the *y*-values to correct their non-normal distribution and performed a Levene test to confirm homogeneity of variance.

**Results**

Of 84 artificial Red-capped Plover nests, 29 (35%) survived the full 18-day study period, 53 (63%) were depredated, and 2 (2%) were destroyed by human activity (one crushed by a four-wheel-drive vehicle and another apparently smashed by children). At all beaches, most nest-depredations occurred within the first 10 days after nests were deployed, and depredations subsequently decreased (mean days to first take = 7.5 ± 0.5 days). Mean number of days to first take did not differ significantly between nests depredated by ravens (7.5 ± 0.8 days, *P* >0.05) and those depredated by foxes (7.8 ± 1.7 days), but the rate of depredation (nests depredated/2 days) by ravens (4.4) was greater than the rate of depredation by foxes (0.9; Predator: *F*<sub>1,15</sub> = 43.24, *P* = 0.001; covariate: Day: *F*<sub>1,15</sub> = 20.89, *P* = 0.001).

Nest survival differed among beaches (Log Rank: *P* = 0.017, Breslow: *P* = 0.015, Tarone–Ware: *P* = 0.016; Figure 2). Depredation of artificial Red-capped Plover nests was greatest at Stockton Beach, where 86% (*n* = 19) of nests were depredated. At all beaches, the depredation rate exceeded, or was equal to, 50%, except at Mungo Beach, where nest-depredation was lowest, at 33% (*n* = 5) of nests.

Ravens depredated 40 (49%) nests, the most of any predator (Figure 3). Comparatively few nests were depredated by foxes and dingoes, which depredated
Figure 2. Percentage of artificial Red-capped Plover nests surviving per 2 days, over the 18-day experimental period, on each of the beaches in the study area on the Lower North Coast of NSW; M = Mungo, LH = Lighthouse, SM = Seven Mile, NM = Nine Mile, LT = Lemontree, S = Stockton; \( n \) = number of artificial nests at each beach indicated.

![Graph showing percentage of nests surviving across different beaches](image)

Figure 3. Percentage of the total number of artificial Red-capped Plover nests deployed that were depredated by each predator species on each of the beaches in the study area on the Lower North Coast of NSW; \( n \) = number of artificial nests at each beach indicated.

![Bar chart showing depredation by species](image)
eight (10%) and two (2%) nests respectively. In two nests (2%), the contents of one egg had been accessed through a small hole pecked or chewed through the shell; the predator of these eggs could not be identified, but was likely a small bird or mammal. At one nest (1% of nests), oystercatcher tracks and fragmented eggshells indicated that a Pied Oystercatcher might have depredated the eggs. Silver Gulls *Chroicocephalus novaehollandiae* did not depredate nests.

**Discussion**

Ravens were the most important predator of artificial Red-capped Plover nests on NSW beaches. Foxes were the second most important predator, but depredated relatively few nests compared with ravens (10% and 49% of artificial nests, respectively). These results and those of other studies (Dunn & Harris 2009; Harris & Dunn 2010) suggest that dingoes and small predators, such as small birds, rodents and small marsupials, are only minor predators of shorebird nests in NSW.

Studies of artificial nests are sometimes criticised for lacking external validity (e.g. Moore & Robinson 2004). Although artificial nests in the present study were not a perfect proxy for natural nests, we suggest that they provide a useful indicator for depredation trends for natural nests of beach-nesting shorebirds for the following reasons: (1) The perceived visual similarity of artificial nests and natural nests. Natural and artificial Red-capped Plover nests were virtually indistinguishable to humans, because of the relative simplicity of their construction, the similar coloration and dimensions of quail and plover eggs, and the perceived similarity of real and artificial nest-sites. (2) The rapidity with which ravens depredated artificial nests. Depredation of natural nests by foxes may be greater during the late stages of incubation, when foxes may detect eggs from the calls and movements of unhatched chicks (J. Dunn pers. comm.). Red-capped Plovers incubate their eggs for ~30 days (Marchant & Higgins 1993). In our study, ravens depredated the majority of nests within the first 10 days. Based on this observation, the impact of raven depredation would still greatly exceed that of fox depredation because ravens depredated most nests before the stage when chicks would become audible inside the eggs. (3) The anti-predator responses of nesting Red-capped Plovers. Incubating Red-capped Plovers have been observed to leave the nest when approached by flying ravens or terrestrial predators and rely on the cryptic coloration of their eggs for the nest to remain unnoticed (Marchant & Higgins 1993). Therefore, it is likely that many Red-capped Plover nests are unattended by parent birds when encountered by foraging predators.

Managers of shorebird breeding areas are often unable to ascribe predators responsible for nest losses because the sand substrate may be either so coarse that it does not hold tracks or so fine that tracks are erased by the sun and wind within hours or days (Harris & Dunn 2010). Conversely, both raven and fox tracks are sometimes observed together at a depredated nest (Maguire *et al.* 2009). Our results are consistent with Mead (2012), who, by placing cameras on real plover nests, found that ravens and Australian Magpies were responsible for a larger number of nest losses than would be evident by solely observing tracks and nest
damage to determine nest fates. We suggest that depredation by ravens could be responsible for many unknown nest fates in nest records maintained by managers of shorebird breeding areas.

At many shorebird breeding areas, managers attempt to control fox populations by shooting, 1080 baiting and trapping, and they protect nests by erecting electric fences and nest cages (Dunn & Harris 2009; Mahon 2009). However, in areas where managers regularly bait foxes, nest losses to foxes are as low as 2% of all nests (Dowling & Weston 1999). In the present study, foxes did not depredate nests on Mungo Beach, where dingoes (which prey upon foxes) are common (Letnic et al. 2011). Some efforts to mitigate depredation by foxes may be misdirected if ravens, rather than foxes, are the chief predators. For example, installing protective cages over shorebird nests can deter mammalian predators, but increase vulnerability of shorebirds and their nests to avian predators, which use cages as a visual cue to locate nests (Murphy et al. 2003; Isaksson et al. 2007; Pauliny et al. 2008). Also, 1080 baiting in areas where dingoes are common can release foxes from depredation and intensify predation pressure on small prey (Letnic et al. 2011).

In comparison with the resources committed to controlling foxes, little is invested in the control of avian predators in NSW. Where lethal control of avian predators has been implemented, it has been highly selective and involved identifying and shooting individual problem birds (e.g. Dunn & Harris 2009). This is because ravens are native predators and are legally protected in national parks and in Camden, the Illawarra and Hunter regions of NSW. Our observations and those of other studies (Harris & Dunn 2010; Mead 2012) suggest that controlling raven populations, wherever the impacts of ravens have been elevated by human activities, will likely expedite the recovery of beach-nesting shorebird populations.

In the present study, depredation of artificial Red-capped Plover nests by ravens was greatest on Stockton Beach. Throughout Australia, ravens have increased in abundance in urban areas, where they have capitalised on waste food and artificial nest-sites (e.g. Recher & Serventy 1991). Potentially, the proximity to Newcastle, the largest urban centre in the region, and frequent camping on the beach have elevated the activity of ravens at Stockton Beach. Consistent with this observation, depredation by ravens was lowest at Mungo Beach, which was the beach most distant from urban areas. Our observations indicate that controlling avian predators at Stockton Beach would improve the breeding success of Little Terns *Sternula albifrons*, Red-capped Plovers and Pied Oystercatchers, which nest there annually.

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References


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