Native and exotic nest predators of Alwal (Golden-shouldered parrot Psephotellus chrysopterygius) on Olkola Country, Cape York Peninsula, Australia

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SHORT COMMUNICATION

Native and exotic nest predators of Alwal (Golden-shouldered parrot *Psephotellus chrysopterygius*) on Olkola Country, Cape York Peninsula, Australia

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ABSTRACT

Nest predation is considered a major cause of population decline for the Endangered Alwal *Psephotellus chrysopterygius* (Golden-shouldered parrot) in Cape York Peninsula, Australia. Camera-traps were installed at 28 Alwal nests across two breeding seasons in four important refuges for the parrot, to confirm nest predator identities and their impact on nesting success. Nest predators were more common at Alwal nests prior to fledging. The feral cat *Felis catus* and yellow-spotted monitor *Varanus panoptes* were the most common predators detected at nests, but the Black-backed butcherbird *Cracticus mentalis*, Pied butcherbird *C. nigrogularis* and Brown goshawk *Acciptier fasciatus* were also documented predating nests. Predators were significantly more common at nests in the days prior to fledging, possibly due to increased nest site activity. Nest success was higher amongst denser vegetation, indicating that cover may inhibit detection of nests by predators, particularly at fledging time. As with many threatened species globally, further monitoring is needed to disentangle knowledge of Alwal nest predation, including refined nest-monitoring techniques to document elusive predation events.

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Grassland-dependent birds; vertebrate pests; invasive species; threatened species; vegetation thickening

Introduction

Fledging success is fundamental for determining the population persistence of birds (Ricklefs 1989). Nesting biology is adaptive to nest predation under natural conditions and can influence time of breeding, clutch size, development rates and nest attentiveness by parents, and the structure, substrate and habitat type of nesting sites (Brightsmith 2005). Habitat change can disrupt these relationships and interact with or facilitate other threatening processes, including heightened predation by native and introduced predators (Stojanovic *et al.* 2014).

The Alwal (Golden-shouldered parrot *Psephotellus chrysopterygius;* Provost *et al.* 2018) is a small (45–55 g) granivorous parrot currently listed as Endangered in Australia (Department of the Environment 2020). The Alwal are one of three Australian parrots known to excavate nests in termite mounds. The closely related paradise parrot *P. pulcherrimus* is now extinct and another congener, the hooded parrot *P. dissimilis* is declining within the Northern Territory (Garnett and Crowley 2002). Alwal were once widespread over Cape York Peninsula (CYP) but have been declining since at least 1920 (White 1922). This decline is thought to be symptomatic of widespread habitat change across CYP since colonisation, due to inappropriate fire regimes, overgrazing by domestic stock, vertebrate pests (i.e. feral pigs *sus scrofus*), woody encroachment into grasslands and altered grassland composition (Crowley and Garnett 1998). These factors have culminated in a decline in habitat quality, and have been implicated in the demise of other grassland-dependent birds (Franklin *et al.* 1999; Garnett and Crowley 2002; Irestedt *et al.* 2019).

Along with altering vegetation structure and composition, vegetation thickening is thought to be negatively impacting survival of Alwal by facilitating predation while foraging and nesting (Crowley *et al.* 2003). Each season approximately 26% of eggs are lost to predation, with an additional 26% of nestlings taken by predators (Crowley *et al.* 2003). Although *Varanus* spp. (monitor lizards) are recognised as a key predator of both eggs and nestlings, the predation pressure of Pied butcherbirds *Cracticus nigrogularis* is thought to be increasing (Crowley *et al.* 2003). These ambush predators may benefit from heightened perch availability associated with vegetation thickening, causing higher rates of adult deaths and nest failures for Alwal in dense vegetation (Crowley *et al.* 2003). There are also recent concerns the

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Supplemental data for this article can be accessed here.

feral cat *Felis catus* may have a significant role in nest predation. Previous assessments of nest predator identity and interactions with vegetation change remain largely anecdotal (Garnett and Crowley 1995). Given the ongoing decline of Alwal, understanding the relative importance of nest predation will provide essential evidence to prioritise predator management strategies.

Camera traps are an increasingly important tool for monitoring nest predation (Stojanovich *et al.* 2017), providing advantages over physical observation by reducing human interference and interpretation of ambiguous predation signs (Guppy *et al.* 2017). By using camera traps, we aimed to examine for the first time, the identity of Alwal nest predators, the relative impacts on Alwal nest success and evidence for the relationship between woody vegetation encroachment and nest success.

Methods

The study was undertaken on the traditional lands of the Olkola People in CYP. The climate is monsoonal and dominant habitats include open eucalypt woodlands and *Melaleuca viridiflora* flats interspersed with ephemeral streams (Garnett and Crowley 2002; Crowley *et al.* 2003).

Searching was undertaken across known Alwal nesting habitat during the nesting season (Preece *et al.* 2009). Nests were inspected to determine the development stage following existing protocols to avoid disturbance (Crowley and Garnett 1995). Camera traps (Reconyx Inc.) were deployed on active nests (n = 28). One camera was placed 1–1.5 m from the nest hole to monitor Alwal parent and nestling activity, with a second camera placed 3–4 m away to monitor predator activity. Thirty active and 46 inactive Alwal nests were located over the two-year period (April to September 2016 and March to October 2017). Re-nesting attempts could not be documented given the periodic survey schedule and consequent uncertainty assigning nest ownership to specific breeding pairs. Cameras were deployed on 28 active nests for 1660 camera-trap nights over both seasons (Appendix 1). Camera failures and missing data reduced the data set to 25 nests. Cameras were collected after the expected fledge date of nests and signs pertaining to nest success were recorded.

All woody, immature (<2 m; >2 m and circumference <20 cm at 1.3 m) and mature (>2 m and circumference >20 cm at 1.3 m) trees were counted 2 m either side of two 50 m transects by walking 50 m north-south and 50 m east-west with the termitaria (nest-site) at the centre. As nests commonly occur on open flats lined with denser trees, sampling a cross-section of vegetation ensured ecotones were captured.

Predator detection rates (events per 100 camera-trap nights) were calculated for each nest site and summed to provide a species-specific total across all sites. Multiple detections of the same individual within one hour were considered the same event. To investigate if predation risk increased due to higher levels of nest-site activity, detection rates were grouped as 'before week six' (early nest development) and 'after week six' (nest maturation approaching fledging at the end of week 8). Predators were also grouped as 'known predators' (e.g. feral cat, predatory birds, *Varanus* sp.) and 'other predators' (e.g. dingo). Two-sample T-tests were used to investigate directional differences between the mean detection-rate of predators at active nests and between nest development periods.

Nest predation, defined as an active attempt to take eggs, nestlings or adult Alwal at the nest, was considered a single event if perpetrated by the same individual within one hour. Clutch size was compared with predation events and successful nests occurred when at least one mature nestling fledged (Berkunsky *et al.* 2016). Nest fate was classified as 'observed' (i.e. camera trap data) or 'inferred'. If undisturbed at the expected time of fledging, success was inferred. Failure was inferred at nests where remains of eggs/birds, damage to the nest, or termites prematurely covering the nest were present (Garnett and Crowley 2002; Berkunsky *et al.* 2016; Guppy *et al.* 2017). Despite attempts to avoid such interpretations, there was a trade-off between increasing sample size for analysis and preserving certainty of predator identity, predation and nest fate.

Relationships between nest fate and predation were analysed using Chi-squared tests for equality of proportions. Two-sample T-tests were used to determine if vegetation density was significantly different between the categories of nest fate and predation. Statistical analyses were computed using R (R Core Team 2017).

Results

Based on direct observation, four nests survived and five failed. Survival and failure were inferred for an additional 57 and 10 nests, respectively. Based on direct observation, predation occurred at five nests and was absent from 18 nests. Predation was inferred at an additional 11 nests, and presumed absent from 43 nests.

Overall, predation accounted for the greatest proportion of nest failures (66.7%; Appendix 5). The proportion of successful nests (n = 61) without predation (n = 56) was significantly greater than those predated (n = 5; χ^2_1 = 82; p < 0.001; Table 1).

Table 1. Nest fate ('success' or 'failure') and nest predation ('predated' or 'not predated') was tested for significance (n = 76) using equality of proportions with a χ^2 distribution.

Category	H_1	χ^2_1	P
Success	Not predated (n = 56) > predated (n = 5)	82.0	<0.001
Failure	Predated (n = 10) > not predated (n = 5)	3.3	0.03
Predated	Fail (n = 10) > success (n = 6)	2.0	0.07
Not predated	Success (n = 56) > fail (n = 4)	86.7	<0.001

When examining observed nest fate only (n = 9), 37.5% of nests survived.

Predation was observed at four of these nests, although 75% (n = 3) successfully fledged young. Observed failures were caused by predation (n = 1) and nest abandonment (n = 4). Nest success was inferred for an additional 17 active nests where predation was not observed but fledging was not photographed. Of predated nests, the proportion of successful nests was not significantly greater than failures χ^2_1 = 0.5; p = 2.0). Of nest failures, the proportion without predation was not significantly greater than those with predation (χ^2_1 = 1.6; p = 0.10).

Vegetation density around predated nests was significantly lower in the >2 m < 20 cm category (T_{25} = 2.3, p = 0.01). Vegetation density around nests with aerial predation (n = 3) was significantly lower (T_{25} = −2.1, p = 0.02; Appendix 2).

The feral cat and dingo were the most active predators with 15.5 and 20.3 detections/100 camera-trap nights, respectively (Appendix 3). The Pied butcherbird was not detected at any nest site, while novel predators included the Black-backed butcherbird *Cracticus mentalis* and Brown goshawk *Accipiter fasciatus*. Detection rates for 'all predators' (T_{48} = 1.6, p = 0.05) and 'known predators' (T_{48} = 1.8, p = 0.03) were significantly greater as Alwal nests approached fledging. Predation events (n = 7) occurred exclusively during week seven (n = 4) and eight (n = 3; Figure 1). The yellow-spotted monitor (n = 2) took two of two, and two of four nestlings. The feral cat (n = 1) took one of four nestlings. Unsuccessful predation events were perpetrated by the feral cat (n = 1), Brown goshawk (n = 1) and Black-backed butcherbird (n = 2). Signs of predation at nests (e.g. beak/claw scratches) suggest additional predation by the butcherbird (n = 1) and yellow-spotted monitor (n = 4).

Detection events of the yellow-spotted monitor (n = 2) and predatory birds (n = 4) were diurnal while 75% (n = 12) of feral cat detection events were nocturnal. All predation events (n = 7) were diurnal, with ~85% (n = 6) between sunrise and 1130 hrs, the period of highest avian activity (Libsch *et al.* 2008). The remaining ~15% (n = 1) were between 1400–1430 hrs. Mean predator detection rates were not correlated with vegetation density in any size class (P > 0.10).

Discussion

Even at low levels, nest predation can have severe impacts on vulnerable bird populations, especially where several apparently minor threats are collectively driving a significant decline. This study attempted to quantify nest predation via camera traps for the first time, as knowledge of this elusive threat is essential to guide management strategies.

Alwal nest success was apparently high in this study, with over 80% of nests fledging at least one young (observed and inferred) compared with 56% in previous surveys (Preece *et al.* 2009). Alwal nest failures were largely caused by predation (73%) and Crowley *et al.* (2003) documented a similarly high proportion of total young lost to predators in comparison to other causes of death (71%). However, given *observed* nest success was only 37.5%, that predated nests were often successful, and nest failures were often

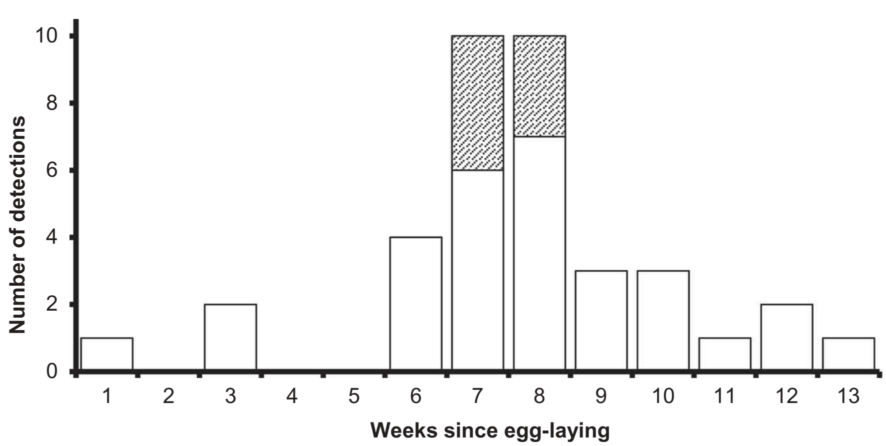

Figure 1. Predator detection events (white) and predation events (stippled) at Alwal nests from week since egg-laying peaked at week 7 (n = 6) and 8 (n = 7), preceding fledging at the end of week 8. Predator detection rates for 'all predators' (T_{48} = 1.6, p = 0.05) and 'known predators' (T_{48} = 1.8, p = 0.03) were significantly higher after week 6, coinciding with nest maturation.

caused by reasons other than predation, further research is clearly needed to inform threat management.

As in previous research, the yellow-spotted monitor was an important predator of Alwal nests in this study. The yellow-spotted monitor took an entire clutch and the greatest number of nestlings overall. The subsequent decline of monitors following cane toad *Rhinella marina* invasion by mid-1980 (Burnett 1997) may have corresponded to the halt in Alwal population decline *c.* 1995 (Preece *et al.* 2009). However, Crowley and Garnett (1995) state *Varanus* spp. had likely recovered in Alwal habitat by 1995. Importantly, if *Varanus* spp. populations are still recovering from cane toad impacts, Alwal nest predation may increase into the future. Monitor populations could also increase with feral cat control (as a predator of juvenile monitors), placing additional predation pressure on predation on preferred prey, including Alwal (Stokeld *et al.* 2018).

The Black-backed butcherbird and Brown goshawk were documented predating Alwal nests for the first time (Appendix 4), highlighting the need for further monitoring to understand key Alwal nest predators. Pied butcherbirds were not detected on camera-traps in this study, contrasting suggestions they are common nest predators (Crowley *et al.* 2003). Similarly, Preece *et al.* (2009) only sighted three Pied butcherbirds during a comparable search period of 1500 km over 25 days. However, five nests in this study had dead nestlings, or nestlings with pierced skulls, consistent with *Cracticus* spp. predation (Appendix 5). Furthermore, the Pied butcherbird was detected via camera trap predating an Alwal nest in 2018 (OAC, unpublished data), reiterating the need for refined nest monitoring techniques to document elusive predation events.

Although Alwal young can only ever be a minor part of a butcherbirds' diet due to seasonal availability, butcherbirds have been observed to stalk and attack Alwal nests on multiple occasions (Shephard, S., pers. comm., June 2017). This native bird is still likely to cause a reduction in breeding succss and there is some evidence that butcherbird abundance has increased throughout the distribution of Alwal (Garnett and Crowley 1995).

With nests typically located below 1 m in termitaria (Garnett and Crowley 2002), Alwal are particularly susceptible to feral cat predation (Woinarski *et al.* 2017); especially considering nest heights are decreasing (Crowley *et al.* 2003). Despite high detection rates of feral cats, only one individual successfully predated an Alwal nest, while one Alwal nest was passed eight times by multiple feral cats (six nocturnal, two diurnal) and was not predated. Vocalisation prior to fledging, or an increase adult/fledgling activity may instigate investigation of Alwal nests by feral cats. With a home range of 2.4–4.4 km^2 (McGregor *et al.* 2016), a feral cat could potentially predate two to five nests within its territory each year, given a density of 0.2–1 nests per km^2 (Garnett and Crowley 2002). This may cause significant losses of Alwal each breeding season, especially if feral cats learned and repeated this behaviour (Dickman and Newsome 2015). Monitoring this threat and exploring culturally appropriate management options is therefore critical.

In contrast to Crowley *et al.* (2003), and recognising our small sample size, there was no relationship between higher woody plant density and Alwal nest success. Predated nests including those attacked by predatory birds occurred in both open and dense areas. The 10 m perimeter for vegetation density (Crowley *et al.* 2003) may be a more meaningful scale for butcherbird hunting compared with the 25 m cross-section used here. It is also possible that denser vegetation at the broader scale measured in this study could inhibit predator detection of Alwal nests.

Consistent with other research (e.g. Libsch *et al.* 2008), predation occurred during foraging times and as nests approached maturity, coinciding with peak nest-activity. Habitat quality can mitigate this predation risk, independent of nest activity levels (Martin *et al.* 2000). At Alwal nests, predation was lower in areas with denser immature vegetation, and the relationship between increased butcherbird perches and nest concealment from predation warrants further investigation (Segura *et al.* 2012). Although the evidence presented here is not sufficient to dismiss previous hypotheses (Crowley *et al.* 2003), finer-scale analysis of Alwal nest sites will be informative regarding the interactions between vegetation thickening and nest success.

Conclusion

Mitigating nest predation represents an opportunity to increase Alwal population abundance. However, predator management can be resource intensive especially over large, inaccessible areas. Considering this, our findings point to four clear management recommendations; (i) determine the feasibility of reducing nest predation by feral cats, yellow-spotted monitors and butcherbirds in Alwal habitat (i.e culling, baiting) with consideration of possible trophic interactions and cultural appropriateness of management strategies, (ii) trial and evaluate suitable predator control strategies at the nest site from week six of nest development (i.e. exclusion, spray traps), (iii) improve nest predation monitoring techniques, and (iv) determine the relative importance of other drivers of decline related to habitat quality, especially at the population contraction zone.

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Disclosure statement

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