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Abstract

Context: Enclosing nests in cages to exclude predators is a management tool frequently used to increase the reproductive success of threatened ground-nesting precocial birds. This technique has seldom been used with passerines, despite the predicted increased benefit for altricial species due to their longer period of nest dependency. **Aims:** The aims of this study were to determine (1) whether cages could be installed around the nests of a threatened, shrub-nesting passerine without causing parental desertion, and (2) whether caged nests could successfully exclude the dominant nest predators and increase nesting success. **Methods:** Cages with four different mesh sizes (1000 mm, 200 mm, 100 mm, 50 mm) were installed sequentially in trials at four nests in a secure population and three nests in an endangered population of white-fronted chats (*Epthianura albifrons*) to investigate susceptibility to desertion. Trials using 160 caged and uncaged artificial nests were used to determine the efficacy of 50-mm wire mesh in preventing access to eggs by potential nest predators. **Key results:** Parent birds accepted nest cages, which reduced predation rates on artificial nests from 96% to 14%. Infrared-triggered cameras revealed that corvids were responsible for 94% of predation episodes. Nest success of caged white-fronted chat nests was 85% ($n = 7$). **Conclusions:** Nest cages do not appear to have negative effects on nest success of white-fronted chats, and may considerably increase reproductive success. **Implications:** Nest cages may aid conservation of the endangered population of white-fronted chats and other endangered songbird species.

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Nest caging as a conservation tool for threatened songbirds

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Abstract

Context. Enclosing nests in cages to exclude predators is a management tool frequently used to increase the reproductive success of threatened ground-nesting precocial birds. This technique has seldom been used with passerines, despite the predicted increased benefit for altricial species due to their longer period of nest dependency.

Aims. The aims of this study were to determine 1) whether cages could be installed around the nests of a threatened, shrub-nesting passerine without causing parental desertion; and 2) whether caged nests could successfully exclude the dominant nest predators and increase nesting success.

Methods. Cages with four different mesh sizes (1000 mm, 200 mm, 100 mm, 50 mm) were installed sequentially in trials at four nests in a secure population and three nests in an endangered population of white-fronted chats (*Epthianura albifrons*) to investigate susceptibility to desertion. Trials using 160 caged and uncaged artificial nests

were used to determine the efficacy of 50-mm wire mesh in preventing access to eggs by potential nest predators.

Key results. Parent birds accepted nest cages which reduced predation rates on artificial nests from 96% to 14%. Infrared-triggered cameras revealed that corvids were responsible for 94% of predation episodes. Nest success of caged white-fronted chat nests was 85% ($n = 7$).

Conclusions. Nest cages do not appear to have negative effects on nest success of white-fronted chats, and may considerably increase reproductive success.

Implications. Nest cages may aid conservation of the endangered population of white-fronted chats and other endangered songbird species.

Additional keywords: corvid, enclosure, *Epthianura albifrons*, nest predation, predator exclusion, saltmarsh

Introduction

Predation of eggs and nestlings is the dominant source of avian reproductive failure, especially among open-nesting species (Ricklefs 1969; Martin and Briskie 2009). It is a powerful selective force on life history characteristics, population size and community organisation (Martin 1988, 1995; Côté and Sutherland 1997; Martin *et al.* 2006). Elevated predation rates from new predators or by increased abundance or efficiency of existing predators, contribute to population and species decline (Schmidt 2003; Jones *et al.* 2008). Many bird species from oceanic islands have become extinct following the introduction of novel nest predators (Blackburn *et al.* 2005; Remeš *et al.* 2012), with predation by exotic species widely recognised as a key threatening process (Salo *et al.* 2007). Some generalist

predators have also increased in abundance through mesopredator release because of loss of top predators, often resulting in elevated predation rates in fragmented landscapes (Wilcove 1985; Crooks and Soule 1999; Schmidt 2003). Similarly, some generalist predators, particularly corvids, have increased in density through exploitation of the anthropogenic matrix of fragmented landscapes, exerting a greater predatory impact (Andren 1992; Huhta *et al.* 1996; Major *et al.* 1999).

With predation typically accounting for 70-95% of nest failure in open-nesting birds (Martin and Briskie 2009), reducing predation rates could potentially boost productivity. Control or eradication of nest predators has been attempted as a management tool to assist in the recovery of species with declining populations (Côté and Sutherland 1997; Smith *et al.* 2010). Notwithstanding ethical issues associated with the destruction of native wildlife (Minteer and Collins 2005), non-selective population control of predators may also be inefficient because the relationship between predator density and impact can be non-linear, with individual predators having disproportionate impacts on prey (Götmark *et al.* 1990; Braysher 1993). Methods of reducing predation efficacy, rather than controlling predator numbers are worthy of investigation.

Enclosing nests with wire cages that permit passage of parent birds while excluding larger nest predators has been attempted as a means of increasing the reproductive success of threatened ground-nesting birds (Rimmer and Deblinger 1990; Murphy *et al.* 2003). Although nest-caging generally increases hatching success (Smith *et al.* 2011), the effect on the population is not always positive because 1) some nest predators are small enough to access caged nests (Johnson and Oring 2002); 2) caging sometimes results in abandonment of nests (Pearson *et al.* 2012); 3) predators can be attracted to nests by cages, or learn to associate cages with nests (Niehaus 2004); or 4) caging may increase rates of predation of

adults, particularly of species that remain on nests until predators are very close (Isaksson *et al.* 2007).

Most nest-caging experiments have been conducted with shorebirds and waterfowl (Smith *et al.* 2011), yet cages provide limited utility for precocial birds because vulnerable chicks leave the protection of the enclosure shortly after hatching. Nest cages have seldom been used to enhance nest success of passerines, possibly because most species nest in trees or shrubs, where mounting cages can be difficult. Caging of passerine nests may achieve even greater demographic benefits because altricial birds are generally free-flying when they leave a caged nest and therefore less vulnerable to predation than precocial birds.

The relatively few accounts of protective caging of passerine nests have delivered increased fledging rates. Open-topped metal cylinders that excluded ground predators significantly reduced predation rates on the saltmarsh-nesting seaside sparrow (*Ammodramus maritimus*; Post and Greenlaw 1989), and plastic-mesh baskets excluded large avian predators from the nests of eastern yellow robins (*Eopsaltria australis*; Debus 2006). Although these manipulations were conducted on common species for experimental purposes, the results demonstrate the potential for nest caging as a management tool for the recovery of endangered passerines. However, improvements in hatching success of the ground-nesting streaked horned lark (*Eremophila alpestris strigata*), were offset by elevated rates of nest desertion (Pearson *et al.* 2012). Further trials are required to evaluate the efficacy of nest caging as a management tool for altricial birds.

The aim of this study was to determine whether nest-caging could be used to prevent the imminent extinction of an endangered population of white-fronted chats (*Epthianura albifrons*) (NSWSC 2010), subject to high predation pressure from corvids invading the species' habitat from adjacent urban areas (Major and Sladek 2012). Specifically, we aimed to determine 1) whether cages could be installed around nests without

causing nest desertion; and 2) whether cages with a mesh size large enough to permit the passage of white-fronted chats could still effectively exclude nest predators.

Materials and methods

Study species

The white-fronted chat is a small (13 g) honeyeater, commonly associated with coastal saltmarsh vegetation (Ashcroft and Major 2013). The species is exclusively insectivorous, and forages on the ground, frequently in flocks of 10–20 birds (Major 1991a). They form monogamous breeding pairs and often nest “semi-colonially” rather than defending all-purpose territories (Major 1991b). Urbanisation and coastal development, particularly along estuaries, has destroyed much coastal saltmarsh, now listed as an endangered ecological community. While still secure at the species level with a geographical range extending across temperate Australia (Barrett *et al.* 2013), the white-fronted chat is listed as a vulnerable species in the northeastern part of its range, while an isolated population in the Sydney region is listed as endangered (NSWSC 2010). One subpopulation of this endangered population is now functionally extinct, with only two males (as of March 2014, R. Major, unpubl. data), while the other consists of ~20 individuals (Major and Sladek 2012). Given the isolation of this population and its vulnerability to nest predators, especially anthropogenically-elevated numbers of Australian ravens *Corvus coronoides* (Major and Sladek 2012), conservation measures are needed to increase population size to avoid local extinction (Major *et al.* 2014).

White-fronted chats build their nests in low shrubs and rushes at a mean height of 23 ± 14 (SD) cm and lay 2- or 3-egg clutches (Major 1991b). Eggs hatch after 14 days; nestlings fly from the nest after a further 14 days; and are fed by their parents for a further

10-15 days. Parents will re-lay after unsuccessful and successful clutches during a breeding season from September to January. Both parents incubate eggs and provision young, with a mean duration of incubation bouts of 27 ± 13 (SD) min. The non-incubating parent generally forages away from the nest site, often joining flocks of foraging individuals (Major 1991a,b).

Parental response to predator-resistant cages

To determine whether parent birds would accept protective cages, nest caging was trialled on a secure population of white-fronted chats near Currarong, New South Wales, 120 km south of Sydney, Australia (34.984 S, 150.773 E) during the spring of 2011 and 2012. This site is a 100-ha area of coastal saltmarsh with the dominant vegetation comprising low shrubs (*Sarcocornia quinqueflora*, *Suaeda australis*, and *Tecticornia arbuscula*), as well as small mangroves (*Avicennia marina*). Four nests were located in *Tecticornia arbuscula* shrubs at a mean nest height of 38.6 ± 4.9 (SD) cm.

Caging trials aimed to investigate the effects of three variables on the probability of nest desertion: 1) the stage of the nesting cycle when cages were introduced; 2) the size of the cage's mesh; and 3) the amount of acclimatisation to less-obstructive cages, before installation of predator-resistant caging. Trials were conducted at four nests, beginning with a stepped approach that required more human intervention, but smaller changes at each step, and finishing with an approach that minimised human intervention by requiring fewer steps but more dramatic changes. We considered the first approach least likely to induce desertion because it involved gradual changes and was implemented later in the breeding cycle. The final mesh-size of cages enclosing nests (50 mm) was designed to exclude what we considered to be the most likely nest predators (Australian ravens), while allowing parent birds to pass through. This was based on personal observations of 50-mm mesh excluding satin bowerbirds *Ptilonorhynchus violaceus* (smaller than Australian ravens) from orchards,

while allowing red-whiskered bulbuls *Pycnonotus jocosus* (larger than white-fronted chats) to pass.

At the first nest, caging of the nest was delayed until nestlings were 7 days old (Table 1). Predator-resistant caging was then introduced in four steps using the same cage dimensions but varying the mesh size at each step. The first cage (1000-mm mesh - Fig. 1) consisted of an 80 x 80 x 100 (height) cm frame of 6-mm steel rod, painted black to reduce visibility. One hour after acceptance was confirmed, it was replaced with a second cage of 200-mm square weldmesh. One hour after confirming acceptance, the second cage was replaced with a third cage of weldmesh covered with 100-mm fine wire mesh. Finally, one hour after acceptance of the third cage, the final, predator-resistant cage of weldmesh covered with 50-mm fine wire mesh, was installed and left in place after acceptance was confirmed (Fig. 1).

At the second nest, cages were installed sequentially following the same four steps, but the trial began the day after the final egg in the clutch of three was laid. At the third and fourth nests, cages were also installed early in incubation (Table 1), but the number of steps of cage introduction was reduced. At the third nest, only the 200-mm and 50-mm mesh cages were used, and at the fourth nest, the 50-mm predator-resistant cage was installed without preliminary steps.

Parental responses to caging were observed from a portable hide, positioned ~30 m from each nest immediately before installing the first cage. Incubating parents always flew from the nest while the hide was being erected. At all nests, the interval between the parent leaving the nest and the observer being positioned in the hide, having installed the cage, was less than 10 mins. The observer recorded the time elapsed until the attending parent returned to the nest, remaining in the hide until each of the parents had visited the nest and completed bouts of incubation or feeding. For all trials, parents recommenced incubation within 35 min,

circumventing our imposed precondition that trials would be abandoned if the parent had not resettled within 60 mins.

After establishing that parents would accept cages, we caged nests of the endangered population in 2013 at Towra Point. This site is located 10 km from the centre of Sydney (34.021 S, 151.156 E) and consists of a 50-ha area of coastal saltmarsh with the dominant vegetation comprising low shrubs and rushes (*Sarcocornia quinqueflora*, *Suaeda australis*, and *Juncus kraussii*) surrounded by *Avicennia marina* mangrove forests. We searched for breeding birds (Major and Sladek 2012) for an average of 9.08 ± 0.17 (SD) hours each week from September to December 2013. A total of three nests were found and caged in two steps (as described for nest 3, above), soon after a complete clutch of three eggs had been laid (Table 1, Fig. 2c).

In all trials, the nest was at least 250 mm from the nearest face of the cage and was secured in position with four steel pegs hammered into the ground. Following installation of cages, nests were checked twice-weekly to determine their outcome.

Efficacy of nest caging

To determine whether potential nest predators were excluded by cages, we conducted an artificial nest experiment at both saltmarsh sites: Currarong and Towra Point. To minimise disturbance of the endangered white-fronted chat population, field experiments were conducted toward the end of the nesting season, between 8 December 2011 and 6 January 2012.

Artificial nests ($n = 40$) consisting of halved tennis balls clad with coconut fibre (Major *et al.* 1996), were set out in two trials at the two sites. Each nest was positioned ~25 cm above ground on a bamboo skewer, pushed into the ground. In each nest, we placed one fresh quail egg and one egg of modelling clay, designed to record the foraging imprints

of nest predators. Both eggs were attached to nests with string to reduce the likelihood of removal by predators (Major *et al.* 1996).

At Towra Point, artificial nests were placed in clumps of *Juncus kraussii* and, at Currarong, in *Tecticornia arbuscula*; preferred nesting substrates of white-fronted chats at those sites. Artificial nests were ~45 m apart (real nests are often spaced < 50 m apart; Major 1992), along 2-km-long transects. Once secured in host plants, nests were randomly assigned to caged or uncaged treatments, with the constraint that no more than three consecutive nests were in the same treatment. For logistical reasons associated with material costs and the difficulty of transporting the large number of cages required, cages used in the artificial nest experiments were smaller than those used to enclose active white-fronted chat nests. Caged nests were covered with 50-cm diameter cylinders of 50-mm wire mesh that stood 50 cm high. Each cylinder was painted black and held in place with four steel pegs so that nests were positioned in the centre of the cages.

Each trial lasted 14 days (incubation period of white-fronted chats), after which nest outcome was recorded and remaining modelling clay examined for beak or tooth imprints. Nests were re-used in the second trial at each site, but in new locations and with fresh eggs. Outcomes of the 160 nests were recorded (2 caging treatments x 2 saltmarsh sites x 2 trials x 20 replicates), with differences in predation outcome between treatment, sites, and trials analysed by log-linear modelling.

Video cameras were used to record predation events during the second trial at the Towra Point site. Surveillance cameras (Scout Guard SG550V; Faunatech, Eltham, Victoria, Australia) attached to wooden stakes were installed ~4 m from each of the 40 nests (20 caged and 20 uncaged). Cameras were motion-triggered using passive infrared sensors, with a 1-s shutter response time and a trigger range of up to 10 m. Each time a camera was triggered, 20 s of video footage was recorded. Each camera contained a 2 gigabyte SD card and was

equipped with an infrared LED flash so no visible flash was produced when cameras were triggered at night. Nests were sometimes visited by more than one predator, but for our analysis, the first animal recorded at the nest was deemed the predator. Cameras were programmed to leave a latency period of 20 s following the end of a segment of video, after which another segment would be filmed if a predator was still moving at the nest at the end of the latency period. By using the time stamp on the video footage, we were able to determine the length of time predators spent near caged nests.

Results

Parental response to predator-resistant cages

At the first nest, both parents returned to the vicinity of the nest 5 min after the 1000-mm mesh cage was installed (Table 1). Initially, they hesitated before feeding the nestlings, flying down to the ground and back up to low perches twice, before flying through the cage to the nest. Both parents had fed their nestlings within 1 min of returning to the nest area, exhibiting behaviour no different from that of parents returning to a nest after the erection of a hide nearby. After installing the 200-mm-mesh cage, the female returned to the nest after 10 min and flew directly to the nest. The male did likewise after a further 12 min. A similar response was observed with the 100-mm-mesh cage. After installing the 50-mm-mesh cage, the male (but not the female) landed on the cage on the first visit, before entering the cage. On subsequent visits, both birds flew directly through the mesh.

Parental reactions at nests 2-4 were similar to those at nest 1, with parents taking between 3 and 35 min to return to the nest following cage installations (Table 1). The greatest hesitation between the return of a parent and incubation was at nest 4. After arriving at the nest site, the returning male made three flights over the cage before entering, but even this hesitation was less than 2 min. None of the four nests was subsequently abandoned and three

of the four nests fledged at least one young (Table 1). The eggs from one nest were apparently depredated, presumably by a predator small enough to pass through the mesh.

Parental behaviour was similar at the three nests of the endangered population caged at Towra Point in 2013 (Table 1). They were undeterred by the cages and each nest produced at least one fledgling seen subsequently to leaving their nests.

Efficacy of nest caging

Cages effectively prevented potential nest predators from accessing artificial nests, reducing overall predation rate from 96% to 14% over the 14-days (Fig. 3). There were no significant 2-way or 3-way interaction effects between treatments, sites, and trials in the log linear models, so the main effects could be considered separately. The effect of the caging was significant ($\chi^2_1 = 107$, $P < 0.001$), and there were no differences in predation rate between study sites ($\chi^2_1 = 0.0$, $P = 1.0$) or between trials ($\chi^2_1 = 0.6$, $P = 0.43$), nor were there any significant interactions.

Most (77%, $n=88$) clay eggs were removed from nests by predators, poorly serving in predator identification. Only nine clay eggs contained identifiable imprints, with eight having large beak imprints and one having imprints of rodent incisors. Surveillance cameras effectively identified predators visiting uncaged and caged nests (Fig. 2a, b), with filmed predators at 17 of 20 uncaged nests and 18 of 20 caged nests. The Australian raven was the dominant predator, accounting for 94% of identified predation events ($n=33$). The swamp harrier (*Circus approximans*) was responsible for the remaining 6 % of predation events ($n=2$). Other potential predators recorded by video were a common brushtail possum (*Trichosurus vulpecular*; $n = 1$) and an unidentified rat (*Rattus* sp.; $n = 1$), but these recordings were after predation by Australian ravens so did not meet our *a priori* definition of predation.

Three cameras failed to collect useful video footage of predators at uncaged nests, and two cameras failed at caged nests. One camera in each treatment was destroyed by seawater from spring high tides, and the memory cards of three cameras were filled to capacity within 24 hours, preventing further recording. This was due to false triggers caused by insects (n=1), windblown vegetation (n=1) and individuals from a mixed flock of foraging Australian white ibis (*Threskiornis molucca*) and white-faced herons (*Egretta novaehollandiae*) (n=1).

Video footage recorded predators walking around cages, jumping on top of them and extending their heads through the cage attempting to reach the eggs. One Australian raven grasped the rim of a nest and pulled it toward the edge of the cage, providing the simplest explanation for depredation of eggs in caged nests.

Predators did not spend long periods attempting to extract eggs from inside cages. Eighty-five percent of attempted predation episodes at successful caged nests ($n = 53$) were < 2 min, with the longest lasting 9 min (Fig. 4).

Discussion

Despite previous observations of white-fronted chats occasionally deserting nests under observer surveillance (Major 1991b), this study suggests that parents will accept cages installed at their nests, regardless of mesh size. Our trials showed that cages are unlikely to have negative demographic impacts. However, our sample size was small and further trials are needed before concluding that 50-mm-mesh cages can be installed directly, without allowing parents to become acclimated to larger-mesh cages. For cages around nests in the endangered population, we adopted a conservative two-step approach because of the slight hesitation between the parent returning to the nest site and it recommencing incubation that was observed when the 50-mm mesh cage was installed directly (nest 4).

Australian ravens were the dominant nest predators of artificial nests, accounting for all except two instances of predation captured on video, supporting previous observations of raven activity at Towra Point (Major and Sladek 2012). However, our results with artificial nest trials cannot be directly extrapolated to infer a similar predator spectrum at natural nests (Major and Kendall 1996; Thompson and Burhans 2004). Installation of nests required inserting a pre-made nest into displaced vegetation, rather than incorporating vegetation into the nest, as in natural nests. Artificial nests were therefore more visible and likely to be more vulnerable to visually-hunting predators, than natural nests. Additionally, our experiment was conducted late in the breeding season when the predator spectrum may be different. However, our objective was simply to determine whether cages could be used to exclude nest predators, rather than to make inference about predation rates on natural nests. Our results showed that cages reduced predation by corvids, known to be important nest predators, even though the relative importance of different nest predators may have been skewed by use of artificial nests (Willebrand and Marcstrom 1988; Thompson and Burhans 2004).

Artificial nests protected by wire cages were 85% less likely to experience predation, indicating that a 50 x 50-mm mesh prevents most predation attempts. Corvids were still able to depredate some caged nests by inserting their heads through the mesh and pulling nests so eggs were within reach, based on video evidence. Predation rates would be even lower if larger cages had been used, increasing the distance between the cage and the nest. Some predation of caged nests was likely to have been caused by predators small enough to enter the cages. One artificial egg at a depredated nest had rodent incisor marks, and one rat was photographed at a nest that had already been depredated, reinforcing evidence that small mammals are primary predators of caged nests (Nol and Brooks 1982; Johnson and Oring 2002).

If artificial nests overestimate predation by visual predators (e.g., corvids), and underestimate predation by olfactory predators (e.g., rats), our artificial-nest experiment may have been biased towards corvid predation. If so, nest caging may not increase reproductive success if implemented at real nests. This was unlikely given that corvids prey on white-fronted chats (Major 1991b) and other birds in Australia (Gardner 1998; Major *et al.* 1999) and worldwide (Andren, 1992; Liebezeit and George 2002). Furthermore, although our sample of real nests was small ($n=7$), the successful fledging of young at 86% of caged nests suggests that caging may have a positive effect on reproductive output, given that nest success in this species is typically low (23%; Major 1991b). Nevertheless, because fledglings must remain within the study site and survive to adulthood before they realise a demographic benefit, further research is needed to determine whether nest caging has a positive effect on overall population size.

While a larger sample size of natural nests, and follow-up monitoring of population size, are required to determine whether nest caging will provide a demographic benefit to the endangered population of white-fronted chats, the findings that parents accept cages, and that cages largely exclude corvids, provide a strong basis for proceeding with nest-caging on the endangered population. An issue that can only be addressed by monitoring a large sample of active nests is whether nest caging might increase adult mortality by restricting the parents' ability to avoid predators that flush them from their nests (Nol and Brooks 1982; Johnson and Oring 2002; Isaksson *et al.* 2007). We think this is unlikely for white-fronted chats because they flush at relatively large distances from approaching predators (Major 1991b; Jenner *et al.* 2011), and mammals do not appear to be important nest predators. Also, predator activity at caged nests might cause nest failure by prolonged disturbance, even if the predators are excluded from the nests. Parent birds leave nests at the approach of a predator (Major 1991b), and a delayed return to the nest with persistent predator attempts could cause parents to desert

nests (Pearson *et al.* 2012). Our data from artificial nests suggest this is unlikely because predators seldom remained at nests for more than 4 min, and never longer than 9 min, intervals unlikely to result in nest desertion. In future caging of natural nests, investigators should also test whether it is worth taking precautions to prevent predators from learning to associate cages with nests by deploying additional cages that are not at nests.

Overall, our results suggest that nest caging is a relatively safe intervention that is likely to boost reproductive success of white-fronted chats. Nest caging also may prove a useful option for conservation of other species of passerine threatened by increased rates of nest predation by elevated populations of predatory birds. Finally, we caution that such interventions must be introduced before populations are reduced to critically low population sizes. The labour-costs involved in finding sufficient nests to protect to produce a demographic benefit increase dramatically as populations decline. The “endangered population of the white-fronted chat in the Sydney Metropolitan Catchment Management Authority” (NSWSC 2010) appears to have declined to four breeding pairs as of November 2014, making recovery through nest-caging a relatively expensive option.

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Table 1. Results of trials to test nest desertion following installation of predator-resistant cages of different mesh sizes at nests of white-fronted chats.

	Nests in secure population (Currarong)				Nests in endangered population (Towra Point)		
	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6	Nest 7
Date caged	20/09/2011	20/10/2011	4/10/2012	6/10/2012	5/09/2013	12/09/2013	18/09/2013
Clutch size	3	3	3	2	3	3	3
Nest stage	7 day nestlings	1 day eggs	2 day eggs	6 day eggs	1 day eggs	1 day eggs	3 day eggs
Time to return to nest:							
1000-mm mesh	5 min	12 min	N/A	N/A	N/A	N/A	N/A
200-mm mesh	10 min	5 min	7 min	N/A	7 min	4 min	35 min
100-mm mesh	3 min	14 min	N/A	N/A	N/A	N/A	N/A
50-mm mesh	11 min	13min	4 min	5 min	5 min	6 min	5 min
Nest outcome	2 chicks fledged, 1 chick died	Eggs depredated	3 chicks fledged	1 chick fledged, 1 infertile egg	2 chicks fledged, 1 infertile egg	3 chicks fledged	2 chicks fledged, 1 infertile egg

Fig. 1. Diagrammatic representation of the four cage types introduced sequentially during caging trials of white-fronted chat nests. Thick lines represent 6-mm weld-mesh; thin lines represent fine wire mesh. The corner squares in the 1000-mm mesh cage were retained to provide structural rigidity.

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Fig. 2. Freeze-frame images from video recordings of (a) Australian raven and (b) swamp harrier at caged artificial nests, and (c) white-fronted chat nest in *Sueada australis* protected by 80 x 80 x 100 cm weldmesh cage covered with 50-mm fine-wire mesh (Nest 6).

Fig. 3. Relative rates of predation on uncaged and caged nests in repeat trials at two separate saltmarsh sites, Towra Point and Currarong ($n = 20$ nests in each treatment in each trial, $n_{\text{total}} = 160$).

Fig. 4. Frequency distribution showing the duration of unsuccessful predation attempts on caged artificial nests by Australian ravens at Towra Point ($n = 53$ attempts at 15 nests).