Bird Conservation International (2009) 19:77–82. © BirdLife International 2009
doi:10.1017/S0959270908008319 Printed in the United Kingdom

Nest protectors provide a cost-effective means of increasing breeding success in Giant Ibis *Thaumatibis gigantea*

OMALISS KEO, NIGEL J. COLLAR and WILLIAM J. SUTHERLAND

Summary

A main cause of nestling loss of the 'Critically Endangered' Giant Ibis *Thaumatibis gigantea* appeared to be mammalian predation. Predator-exclusion devices were added to a randomly selected half of 52 nesting trees, with the other half acting as controls. The number of young fledged per nest was 50% higher for protected nests than control nests. Each protected nest produced almost two-thirds (0.63) of an extra chick. During the nestling period, the daily nestling survival rate was (99.9%) (equivalent to 90% survival over the nestling period) for protected nests and 99.3% (61.3% survival over the whole period) for control nests. Nest protection devices cost US$5 per tree. Each extra nestling fledged as a result of this intervention therefore cost $8. If it was also necessary to pay to locate the nests, then the cost of protecting each nest would be $140 and the cost of producing each extra chick $224. Trees with protectors added were significantly more likely to be reused in the next year than unprotected trees.

Introduction

Many bird species have low breeding success as a result of nest predation (Newton 1998), and management interventions to increase this success have been implemented for some species of birds. Predator-exclusion experiments have produced enhanced egg and nestling survival rates and significantly increased nesting success (Côté and Sutherland 1997). For example, the introduction of concrete hanging boxes for tits *Parus* spp. in an English woodland, in order to reduce predation by Common Weasels *Mustela nivalis*, resulted in higher breeding density (Dunn 1977). Nest-boxes on poles fitted with sheet-metal predator-guards for Black-bellied Tree-ducks *Dendrocygna autumnalis* in North America improved nesting success by around 30% (Bolen 1967). Covering nests with cages in North Dakota and Montana increased the fledging rate in Piping Plovers *Charadrius melodus* (Murphy *et al.* 2003) and Killdeer *Charadrius vociferus* (Johnson and Oring 2002).

The Giant Ibis *Thaumatibis gigantea*, known historically from Peninsular Thailand, Cambodia, southern Laos and southern Vietnam, has dramatically contracted its range and declined in numbers, and is now listed by IUCN as 'Critically Endangered' (IUCN 2006), with a global population estimated at fewer than 250 individuals (Rose and Scott 1997). Northern and eastern Cambodia, where the species was fairly abundant, at least locally, in the early twentieth century (Delacour 1929), now holds the majority of the known population (BirdLife International 2001).

In the course of initial studies into the ecology and conservation of the Giant Ibis, and surveys in northern Cambodia supported since 2001 by the Wildlife Conservation Society (WCS), clear evidence emerged that Common Palm Civets *Paradoxurus hermaphroditus* and/or Yellow-throated Martens *Martes flavigula* were preying upon nestlings and thereby considerably suppressing breeding success. In September 2004, two approximately 30-day-old nestlings were found dead in one nest; claw marks were present on the tree and there was a civet's faeces at its base. A month later, a nest with two nestlings around 60 days old was preyed upon: remains of the nestlings were found below the nests and again claw marks were seen on the tree. Altogether five nests with 10 chicks were observed in 2004 in Chhep district and, of these, seven chicks were predated.

There have been records of birds unsuccessfully attempting to take Giant Ibis. In September 2004 a Changeable Hawk-eagle *Spizaetus cirrhatus* was seen attacking a Giant Ibis nestling about 45 days old. However, the nestling defended itself, the eagle abandoned the attack and the chick went on to fledge successfully. Davidson and Tan (2001) described a hawk-eagle fighting with an adult Giant Ibis at a nest, also without success. In August 2003 a wildlife ranger reported an unsuccessful attack by a Large-billed Crow *Corvus macrorhynchos* on a small nestling.

In view of the apparent seriousness of this issue, an experiment was set up in the following two years to test whether nest protectors might be effective in reducing nestling predation and improving breeding success. These would exclude mammal and snake predators but not birds.

With increasing interest in the cost-effectiveness of conservation interventions (e.g. Murdoch *et al.* 2007) we also calculated the cost of the intervention and the cost per chick saved.

Methods

The study was conducted at Kulen Prumtep Wildlife Sanctuary (Kulen district) and Preah Vihear Protected Forest (Chhep district) in Preah Vihear province, northern Cambodia, in the area bordering Thailand and Lao PDR. This area consists mainly of dipterocarp forest and seasonal and permanent wetlands, with a low human population engaged largely in small-scale agriculture.

As part of a general study of the breeding ecology of the Giant Ibis, nest-finding commenced as soon as the breeding season started in late June in the three years 2004–2006. Seven teams were deployed to look for nests throughout the study site. As soon as a nest was found, nest monitoring was implemented.

A total of 52 nests were monitored, five of 28 nests found in 2004, 22 of 27 found in 2005 and 25 of 28 found in 2006, by a team leader, field assistants and staff of WCS. The nests were generally checked every 5–7 days, although flooding occasionally restricted access for intervals of up to 15 days. Nests were checked at a distance of at least 50 m from the nest tree, with observers concealing themselves in vegetation to minimize disturbance of, or detection by, the adult birds, and hence to reduce any possible observer effect on breeding success (Verboven *et al.* 2001). Whenever a nestling disappeared, the area directly underneath the nest was visited to look for evidence of its fate.

The incubation and nestling periods were calculated from five nests that were closely monitored from the start of the breeding cycle. The hatching date was taken as being the mid-point between the last record of incubation and the first record of a chick in the nest. Similarly, the fledging date was taken as being the mid-point between the last record of a chick in the nest and first record of a chick flying. Clutch size was determined by counting eggs whenever these were seen or by counting chicks when they were first seen in the nest. Given the possibility of egg loss or failure to hatch, it is likely that these methods slightly underestimated the true number of eggs laid in the nests monitored.

The predator-exclusion experiment was conducted over the course of the 2005 and 2006 breeding seasons. A plastic belt 80 cm in height was fixed to the lower trunk of the nest-tree, at least 1.5 m up from the base (Figure 1). This device was sufficiently hard and smooth to prevent upward access by any animals that use claws to climb trees, and might also exclude some snakes. Each device cost US$5. Roughly half (51%) the nests were protected (11 of 22 in 2005 and 13 of 25 in 2006) with the remainder left as controls. Nests were assigned at random to the experimental protection and control treatments. The predator-exclusion devices were added only after hatching in order to avoid the risk of causing desertion of nests during incubation. Each device was fitted at night or in low-light conditions at dawn, and took around five minutes to affix.

The Mayfield method (Mayfield 1961, 1975) was used to estimate daily nest survival probabilities. This method provides an unbiased estimate, by taking into account the number of days

Figure 1. Predator-exclusion belt used for preventing access by mammalian predators to trees with Giant Ibis nests. Photo: Omaliss Keo.

during which the nest was monitored. It assumes a constant daily survival rate (Hensler and Nichols 1981).

Giant Ibises are presumed to lay eggs at the same rate as other ibises, which is one egg per 1–2 days (Hancock *et al.* 1992). The egg-laying interval in the Giant Ibis was therefore assumed to be 1.5 days, which is also the time assumed to be taken to lay a full clutch, as the Giant Ibis almost always and perhaps invariably lays two eggs (see Results). Overall survival rate (S_n) during the entire incubation period was calculated as S_d^J, where J is the duration of incubation. Overall survival during the nestling period was calculated in a similar manner. The standard error of S_n was derived from the variance, which was estimated using the method of Hensler (1985). Nest protection was added soon after hatching so that its impact was determined for the nestling but not the incubation stage.

Results

Based on the number of chicks observed in nests, Giant Ibises almost always lay two eggs per clutch. From the 74 nests found during 2003–2006, the mean clutch size was at least 1.93 eggs; 69 nests (93%) must have held two eggs, and five nests (7%) either held one egg or two eggs of which only one hatched (or possibly the second nestling died very soon after hatching). The incubation period of the Giant Ibis was determined as 32 ± 1.16 days and the nestling period (period from hatching to fledging) was 70 ± 4.64 days. Daily survival during incubation was 99.28 ± 0.29 or 77.62 ± 7.34 over the entire incubation period.

The number of young produced was higher for protected nests (Table 1). Some trees were used for nesting in both years and on six occasions they had the same treatment in both years

Table 1. The success of Giant Ibis nests with and without predator-exclusion devices. The number of chicks fledged is significantly higher for protected nests (Mann Whitney, $U = 196$, $P = 0.002$). This is also significant after excluding the six nests that had the same treatment on the same tree in the previous year ($U = 117$, $P = 0.011$). The survival rates were significantly higher for protected nests ($Z = 2.12$, $P = 0.017$). The estimated survival is the survival for nests protected over the entire nestling period.

	Number of nests	Number of chicks fledged	Chicks per nest	Success	Daily survival Mayfield estimate	Estimated survival over nestling period
Protected	24	45	1.875	93.75	99.85 ± 0.15	90.00 ± 9.48
Unprotected	28	35	1.250	67.31	99.30 ± 0.21	61.30 ± 9.04

(protected for five trees and unprotected for one). The simple comparison of chicks produced thus includes some pseudoreplication. If the second year is removed from the analysis for these six trees to avoid pseudoreplication, then the result is still significant (Table 1). The daily survival rate of chicks was significantly higher when protected than when not (Table 1), so resulting in more offspring. Trees with nest protectors were reused the next year on 72.7% (8/11) of occasions, but when not protected only 9% (1/11) were reused (Fishers exact test $P = 0.0075$).

The cost of the predator-exclusion device was US$5 per nest. The annual reproductive output was 1.25 chicks per pair at unprotected nests and 1.875 chicks per pair at protected nests, yielding an average improvement in breeding success per nest of 0.625 chicks (a 50% improvement). Therefore it cost US$8 (5/0.625) per chick gained from protecting the nest against tree-climbing predators. These nests had already been found, so in this case it is not necessary to include nest finding in the costs. However, we can also work out the cost if it were also necessary to pay for nest finding, as would often be the case. The cost of finding nests using locally recruited teams was $7,560 per annum. This consisted of employing fourteen people for 6 months, of which 2–3 months was spent finding nests and three months monitoring the nests (we assume the cost of nest finding is half of the total, $3,780). Thus the average 28 nests found each year in Kulen and Chhep cost $135 per nest. If we include the cost of the nest guard, protection costs $140 per nest, and the cost per extra chick produced including nest finding is then $224 (140/0.625).

Discussion

Human interventions have had positive effects on populations of 'Critically Endangered' bird species, preventing their extinction (Butchart *et al.* 2006). With a global population estimated at fewer than 250 mature individuals, there is a clear need to increase numbers of the Giant Ibis. The deployment of predator-exclusion belts on more nest-trees of the Giant Ibis across northern Cambodia is therefore urgently required, as a cost-effective means of enhancing breeding output, even if it is necessary to include the costs of finding the nests. However, many areas have already employed wildlife rangers on the ground, so the cost of protection will then only involve the belt itself. Indeed, there now exists a network of local conservation NGO staff as well as rangers throughout the area, so that their information can be harnessed at considerably lower cost than before. Some trees are reused and this is especially true after the tree is protected, which will reduce the effort of finding nests in subsequent years. Thus the overall costs of nest protection are likely to be much lower in the future than they have been up to now.

Acknowledgements

This work was generously supported by the Wildlife Conservation Society, World Wide Fund for Nature, Oriental Bird Club, Club 300 for Bird Protection, Waterbird Society, Joe and Rosa Frenkel

Trust, BirdLife International, University of East Anglia, Zoologische Gesellschaft für Arten- und Populationsschutz, and RSPB. We also thank Ty Sokhun, Colin Poole, Joe Walston, Tom Clements, Tom Evans, Jonathan Eames, Will Duckworth, Dave Showler and Jenny Gill for their kind help and Paul Dolman, Peter Frederick, Margaret Kinnaird, Stuart Marsden, Hugh Wright and an anonymous referee for very useful comments.

References

BirdLife International (2001) *Threatened birds of Asia: the BirdLife International Red Data Book*. BirdLife International, Cambridge, U.K.

Butchart, S. H. M., Stattersfield, A. J. and Collar, N. J. (2006) How many bird extinctions have we prevented? *Oryx* 40: 266–278.

Bolen, E. (1967) Nesting boxes for Black-bellied Tree Ducks. *J. Wildl. Manage.* 31: 794–797.

Côté, I. M. and Sutherland, W. J. (1997) The effectiveness of removing predators to protect bird populations. *Conserv. Biol.* 11: 395–405.

Davidson, P. and Tan, S. (2001) Description and observation of a giant ibis *Pseudibis gigantea* nest in Preah Vihear, Northern Cambodia, August 2001. Unpublished report. Phnom Penh: Wildlife Conservation Society and Wildlife Protection Office, Department of Forestry and Wildlife.

Delacour, J. (1929) On the birds collected during the fourth expedition to French Indo-China. *Ibis* 5: 193–220.

Dunn, E. K. (1977) Predation by weasels (*Mustela nivalis*) on breeding tits (*Parus* spp.) in relation to the density of tits and rodents. *J. Anim. Ecol.* 46: 633–652.

Hancock, J., Kushlan, J. and Kahl, M. P. (1992) *Storks, ibises and spoonbills of the world*. New York: Academic Press.

Hensler, G. L. (1985) Estimation and comparison of functions of daily nest survival probabilities using the Mayfield method. Pp. 289–301 in B. J. T. Morgan and P. M. North, eds. *Statistics in ornithology*. Berlin: Springer Verlag.

Hensler, G. L. and Nichols, J. D. (1981) The Mayfield method of estimating nest success: a model, estimators and simulation results. *Wilson Bull.* 93: 42–53.

IUCN (2006) *IUCN Red List of threatened species*. Gland, Switzerland: IUCN.

Johnson, M. and Oring, L. W. (2002) Are nest exclosures an effective tool in plover conservation? *Waterbirds* 25: 184–190.

Mayfield, H. F. (1961) Nesting success calculated from exposure. *Wilson Bull.* 73: 255–261.

Mayfield, H. F. (1975) Suggestions for analysing nest success. *Wilson Bull.* 87: 456–466.

Murdoch, W., Polasky, S., Wilson, K. A., Possingham, H. P., Karieva, P. and Shaw, R. (2007) Maximizing return on investment in conservation. *Biol. Conserv.* 139: 375–388.

Murphy, R. K., Greenwood, R. J., Ivan, J. S. and Smith, K. A. (2003) Predator exclusion methods for managing endangered shorebirds: are two barriers better than one? *Waterbirds* 26: 156–159.

Newton, I. (1998) *Population limitation in birds*. London: Academic Press.

Rose, P. M. and Scott, D. A. (1997) *Waterfowl population estimates*. Second edition. Wageningen: Wetlands International.

Verboven, N., Ens, B. J. and Dechesne, S. (2001) Effect of investigator disturbance on nest attendance and egg predation in Eurasian oystercatchers. *Auk* 118: 503–508.

OMALISS KEO*

School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, U.K., Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, U.K., *and Wildlife Protection Office, Forestry Administration, Ministry of Agriculture Forestry and Fisheries, 40 Norodom Blvd, Phnom Penh, Cambodia.*

NIGEL J. COLLAR
BirdLife International, Wellbrook Court, Girton Road, Cambridge CB3 0NA, U.K.

WILLIAM J. SUTHERLAND
Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, U.K.

**Author for correspondence; e-mail: omaliss@gmail.com*

Received 12 May 2008; revision accepted 8 June 2008