

Effect of camera monitoring on survival rates of High-Arctic shorebird nests

Laura McKinnon¹ and Joël Bêty

Chaire de Recherche du Canada en Conservation des Écosystèmes Nordiques and Centre d'Études Nordiques, Université du Québec à Rimouski, 300 Allée des Ursulines, Rimouski, Québec, Canada, G5L 3A1

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ABSTRACT. Monitoring bird nests with cameras provides an opportunity to identify the cause of nest failure and record the behavior of individuals. However, leaving an object continuously within sight of a nest could have potential negative effects on nesting success. We compared daily survival rates of nests monitored using cameras and human visitation to nests tracked via human visitation only to test for potential additional effects of camera monitoring on predation rates. From 2006 to 2008, experiments were conducted on Bylot Island (Nunavut) using 80 artificial nests and 53 real nests of Baird's Sandpipers (*Calidris bairdii*) and White-rumped Sandpipers (*Calidris fuscicollis*). Rates of predation on real and artificial nests varied considerably among years. However, survival rates of camera-monitored nests did not differ from those of nests monitored without cameras. Predators of artificial nests included Arctic foxes (*Vulpes lagopus*), Glaucous Gulls (*Larus hyperboreus*), and Long-tailed Jaegers (*Stercorarius longicaudus*), whereas Arctic foxes were responsible for all camera-recorded predation events at real nests. Camera monitoring should be promoted as a viable method for monitoring nests of Arctic shorebirds because our results indicate that placing cameras at nests does not bias estimates of nest survival obtained via nest visits.

SINOPSIS. El efecto del monitoreo con cámaras sobre las tasas de sobrevivencia de los nidos de las aves playeras en el ártico

El monitoreo con cámaras de los nidos de las aves provee una oportunidad para identificar la causa del fallo de los nidos y para documentar el comportamiento de los individuos. Sin embargo, dejar un objeto continuamente a la vista del nido podría tener efectos negativos sobre el éxito de la nidificación. Comparamos las tasas de supervivencia diaria de nidos monitoreados usando cámaras y visitación de personas a la de los nidos que fueron monitoreados solo mediante la visitación de personas para determinar si existieron efectos adicionales del monitoreo con cámaras a las tasas de depredación. Desde 2006 – 2008, realizamos experimentos en la Isla de Bylot (Nunavut) usando 80 nidos artificiales y 53 nidos naturales de *Calidris bairdii* y de *C. fuscicollis*. Las tasas de depredación de nidos naturales y artificiales variaron considerablemente entre años. Sin embargo, las tasas de supervivencia de nidos monitoreados con cámaras no tuvieron diferencias con los que fueron monitoreados sin cámaras. Los depredadores de nidos artificiales incluyeron zorros (*Vulpes lagopus*) y aves (*Larus hyperboreus* y *Stercorarius longicaudus*). Los zorros fueron responsables para todos los eventos de depredación de los nidos naturales grabados con las cámaras. El monitoreo con cámaras debería ser promovido como un método viable para el monitoreo de nidos de playeros en el ártico porque nuestros resultados indican que el uso de las cámaras no afecta a las estimaciones de la supervivencia de los nidos obtenidas mediante visitas a los nidos.

Key words: artificial nests, *Calidris bairdii*, *Calidris fuscicollis*, camera, egg predation

Obtaining estimates of avian nest survival generally requires repeated visits to the same nest to determine nest fate (Mayfield 1961, 1975). As such, effects of investigator disturbance are common in studies of nesting birds (Major 1990, Götmark 1992, Bêty and Gauthier 2001). Although nest survival models are able to partly incorporate the effects of observer visits (Rotella et al. 2000), observer effects may reduce the reproductive success of the individuals studied

(Major 1990, Tulp et al. 2000). Reducing this bias is therefore important, especially when studying declining populations where accurate vital rate information is needed.

Recently, many investigators have monitored nests with cameras to identify predators and limit the number of nest visits (McQuillen and Brewer 2000, Keedwell and Sanders 2002, Sanders and Maloney 2002, Stake and Cimprich 2003, Richardson et al. 2009). Monitoring nests with cameras can decrease the number of visits to nests, while simultaneously recording otherwise unobtainable information on feeding ecology, nesting behavior, and nest predation (Cutler

¹Corresponding author. Email: laura.mckinnon3@gmail.com

and Swann 1999). However, leaving an object within sight of a nest may affect the probability of predation (Herranz et al. 2002).

Monitoring nests with cameras may increase the probability of nest predation if cameras attract predators. If cameras are conspicuous, predators may learn to associate cameras with nests, thereby increasing predation rates (Cartar and Montgomerie 1985). Alternatively, placing conspicuous markers at nests could decrease the probability of predation if some predators avoid cameras or other surveillance units (Hernandez et al. 1997, Sequin et al. 2003). In a recent review and meta-analysis of camera effects on temperate-breeding songbirds, Richardson et al. (2009) found evidence suggesting that camera monitoring did reduce nest predation rates.

If monitoring nests with cameras does affect nest survival, these effects may be particularly evident for Arctic-nesting birds, such as shorebirds, that nest primarily in areas with little to no cover (Cartar and Montgomerie 1985, Smith et al. 2007). Identifying shorebird nest predators and determining the possible effects of camera monitoring on nest predation, over and above that of observer effects, could be important for accurately estimating vital rates of declining shorebird populations (Liebezeit and Zack 2008).

Our primary objective was to compare the survival rates of nests monitored using cameras and human visitation to those of nests monitored only by human visitation to determine the possible effects of camera monitoring on predation rates. Experiments were conducted using artificial nests and the real nests of Baird's Sandpipers (*Calidris bairdii*) and White-rumped Sandpipers (*Calidris fuscicollis*). We also examined the relative importance of different predators based on camera-recorded predation events at real and artificial shorebird nests.

METHODS

Our study was conducted from 2006 to 2008 in an 8 km² study area in the Qarlikturvik Valley located in the Bylot Island Migratory Bird Sanctuary in Sirmilik National Park (72° 53' N, 78° 55' W), Nunavut territory, Canada. The valley is characterized by lowlands composed of mesic tundra and polygonal wetlands and uplands dominated by mesic and xeric tundra (Tremblay et al. 1997). On Bylot Island, the two

most abundant nesting shorebirds are Baird's and White-rumped sandpipers. Both species nest on the ground in small scrapes devoid of nest cover at relatively low densities (<10 nests/km²). Potential predators of shorebird eggs on Bylot Island include Arctic foxes (*Vulpes lagopus*), ermine (*Mustela erminea*), Sandhill Cranes (*Grus canadensis*), Glaucous Gulls (*Larus hyperboreus*), Long-tailed Jaegers (*Stercorarius longicaudus*), Parasitic Jaegers (*S. parasiticus*), and Common Ravens (*Corvus corax*).

Artificial nests. In 2006 and 2008, artificial nest experiments were conducted to determine if the presence of a camera affected the risk of predation while controlling for spatial, temporal, and behavioral heterogeneity associated with real nests. Artificial nests ($N = 40$) were randomly placed in an upland mesic habitat, 10 each within four 1 km² blocks, covering a total area of approximately 4 km² in our 8 km² study area. Each artificial nest consisted of two quail (*Coturnix japonica*) eggs placed in a small depression (scrape) on the tundra. A nail wrapped in florescent orange flagging tape was inserted into the ground in the middle of each scrape under the eggs so predated nests could be easily relocated. All nests were marked with a 12-cm wooden stick (medical tongue depressor) inserted into the ground 5 m from the nest. Also, a natural object (feather or rock) was placed approximately 2 m from the stick on the opposite side of nests. Artificial nests were deployed during the late shorebird incubation period (16 July 2006 and 24 July 2008) between 20:00 and 23:00, and were visited daily for 8 consecutive days.

Real nests. We searched for the nests of Baird's and White-rumped sandpipers during the early laying and incubation periods. Nests were marked as described for artificial nests, but no nail was inserted in the ground under the eggs. Incubation stage was estimated for each nest using the flotation method (Liebezeit et al. 2007). The duration of the incubation period is 21 days for both species and chicks generally leave the nest within 24 h of hatching (Moskoff and Montgomerie 2002, L.M. and J.B., unpubl. data). Nests were visited every 2–5 d during incubation. Within 2 d of the estimated hatch date, nests were visited daily to maximize the probability of recording nest outcome (mean visit frequency = 2.1 ± 0.9 [SE] in 2006 and 4.3 ± 0.9 in 2007). If an empty nest was found

near the date of hatching, determining if the nest was successful or had been predated just prior to hatching was difficult. Nests were considered successful (at least one egg hatched) if one or more of the following criteria were met: (1) chicks were found in the nest, (2) remnants of egg shells were found in the nest material close to the estimated hatch date (Mabee et al. 2006), (3) eggs were hatching (starred and/or pipped) on the last date visited and the nest was empty on the next visit, and (4) the nest was empty on the last visit and the banded adult was later seen with chicks. A few nests ($N = 3$ in 2006 and $N = 1$ in 2007; three without cameras and one with a camera) were not included in our analyses because they were abandoned after adults were banded.

Treatment for artificial and real nests.

Cameras (Model PM35T25, Reconyx, La Crosse, Wisconsin) were randomly assigned to half of the artificial nests in 2006 and 2008. Cameras were also assigned to every other real nest found during the incubation period in 2006 and 2007 and were placed at nests as soon as possible after nests were found and remained there until young fledged or the nest failed. Assigning cameras to every other real nest allowed us to sample evenly across the incubation period, thus decreasing potential bias associated with the nest age. Because any delay between nest finding and camera deployment can equalize nest survival among treatments, we tried to deploy cameras as fast as possible. For most camera-monitored nests (70%), deployment occurred within 24 h of finding the nest. No nests failed during the interval between nest finding and camera deployment. In 2006, cameras were placed on the ground, 15 m from real nests and 10 m from artificial nests as a precautionary measure but were moved closer (5 m from real and artificial nests) in 2007 and 2008. Cameras were equipped with a Passive InfraRed (PIR) motion detector housed in a muted green, waterproof plastic case ($16 \times 10 \times 22$ cm) that was well camouflaged. In 2006, cameras at artificial nests were placed on a tripod (0.75-m high) and equipped with an external trigger housed in a black plastic case ($5.5 \times 7 \times 12.5$ cm). The external trigger extended from the camera to the nest via a 5-m gray cable. When triggered, cameras were programmed to take five photos as fast as possible (up to 5 per second). In addition, one photo was taken every 10 s (except for

artificial nests in 2006) in an attempt to capture any nonmotion-triggered predation events. Artificial nests, with and without cameras, were visited daily. Real nests monitored with cameras were visited at approximately the same frequency (mean visit frequency = 1.7 ± 0.9 in 2006 and 2.5 ± 1.1 in 2007) as real nests without cameras (one sample *t*-test between treatments: 2006, $t_{38} = 1.1$, $P = 0.28$; 2007, $t_{11} = 2.1$, $P = 0.06$).

Predator identification. Shorebird nests and eggs were well camouflaged on the tundra and were not conspicuous in photos taken > 5 m from nests. Hence, the position of each nest (real and artificial) was located on photos by having the camera take a picture of the observer pointing their hand in the position of the nest. Thus, when the nest was not clearly visible on the photos or the predator was not clearly photographed with eggs in its mouth, predator identification was confirmed by photos of the predator with its head situated at the specific nest site indicated by the observer. When these criteria were not met, but there was still evidence of a predator (i.e., a photograph of a predator was taken within a few meters of a predated nest), the predator was recorded as identified with uncertainty. In 2008, we placed cameras at all real nests ($N = 10$) for predator identification (i.e., no test of camera effects was conducted).

Statistical analyses. Differences in predation risk between treatments for artificial nests were calculated using the Cox proportional hazards regression (Cox 1972; PROC PHREG in SAS, Heisey et al. 2007). Cox proportional hazards regression is ideal for predation experiments designed to determine if an applied treatment increases vulnerability to predation (Fox 2001). The test is also advantageous for artificial nest experiments because it permits the incorporation of right-censored data points (nests that survive past the end of the study). One assumption of the Cox approach is that the survival and hazard functions being compared are proportional to each other (i.e., not time dependent). Violation of this assumption was tested graphically (Hess 1995). As survival and hazard functions for the year were not proportional, analyses were stratified by year.

For real nests, we were interested not only in measuring the relative risk of predation for nests with cameras, but, more importantly, how this risk affects daily nest survival, a more meaningful

Table 1. Proportion of successful nests (successful/total number of nests) of Baird's and White-rumped sandpipers by treatment, year, and species.

Nest type	Year	Species	Camera	No camera
Artificial ^a	2006		0/20	1/20
	2008		4/20	3/20
		Total	4/40	4/40
Real	2006	Baird's	0/13	3/14
		White-rumped	0/6	0/7
		Total	0/19	3/21
	2007	Baird's	4/5	3/3
		White-rumped	3/3	1/2
		Total	7/8	4/5

^aArtificial nests were considered successful if not predated by the end of the 8-d exposure period.

biological parameter. Daily nest survival estimates for real nests were estimated with the nest survival option of program MARK (Dinsmore and Dinsmore 2007). Exposure days for camera-monitored nests began the day the camera was placed at the nest to ensure that estimates were not artificially inflated by the incorporation of days monitored without cameras. We felt that this method of establishing exposure days provided the most conservative estimate of daily

nest survival for camera-monitored nests. Exposure days for nests monitored without cameras began the day a nest was found. Only exposure days during the incubation period were included to decrease heterogeneity associated with the nesting stage. When separated by species (Table 1), our sample size was not large enough to generate and select among complex nest survival models including nest age covariates and interactions. Nest survival estimates were thus derived from a simple model with year and treatment effects only. Daily nest survival estimates from this model were presented graphically and the significance of each effect (year and camera) was judged based on whether or not their coefficients had confidence intervals overlapping zero (Dinsmore and Dinsmore 2007). All statistical tests are two sided, and statistical significance and confidence intervals (CI) are based on $P < 0.05$.

RESULTS

Artificial nests. The proportion of artificial nests predated after an 8-d exposure period was high in both years (with and without cameras; Table 1). Survival function curves differed between years (Fig. 1), but the difference was

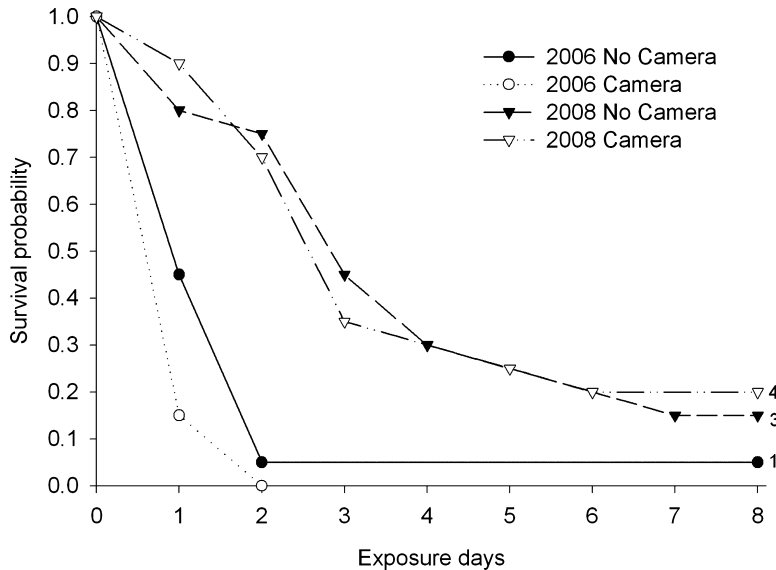


Fig. 1. Survival probabilities for artificial nests with and without cameras in 2006 and 2008 ($N = 20$ per treatment per year). The number of nests that survived past the end of the experiment is indicated at Day 8 for each of the survival curves.

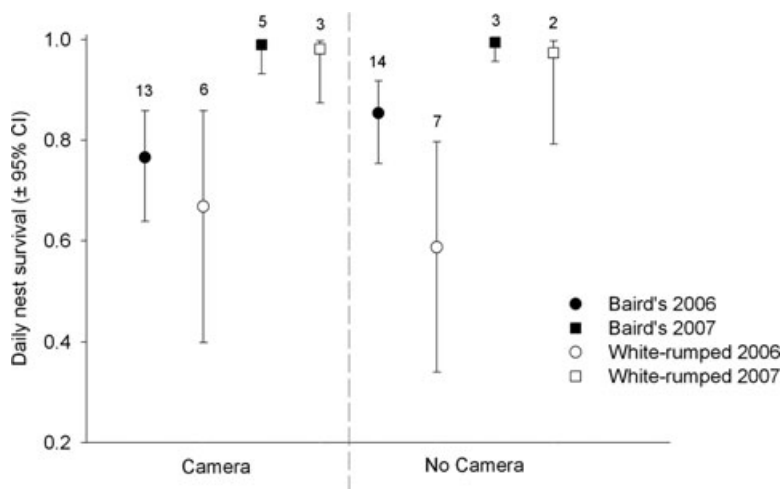


Fig. 2. Daily nest survival of Baird's and White-rumped sandpiper nests (with and without cameras) monitored in 2006 and 2007. Sample sizes are provided above each estimate.

nonproportional (precluding the use of Cox regression to test for the year effect). However, after only 2 d of exposure, the proportion of predated nests differed between years ($\chi^2_1 = 15.7$, $P < 0.001$; Fig. 1). When stratified by year, survival functions did not differ significantly between nests monitored with cameras and those without (likelihood ratio $\chi^2_1 = 0.5$, $P = 0.47$, Fig. 1).

Real nests. We located and monitored 53 nests. The proportion of successful nests and the daily nest survival rate varied between years for both species (Table 1, Fig. 2), but no significant effect of camera monitoring on daily nest survival was detected (Fig. 2). Daily nest survival estimates for Baird's Sandpipers differed between years (year effect = 3.41, 95% CI = 1.38–5.44), but no effect was detected between the two treatments (treatment effect = -0.58, 95% CI = -1.47–0.31). Daily nest survival estimates for White-rumped Sandpipers differed between years (year effect = 3.26, 95% CI = 1.08–5.44), but no effect was detected between treatments (treatment effect = 0.35, 95% CI = -1.11–1.81).

Predators. For artificial nests, predator composition differed between years. Arctic foxes were responsible for all recorded predation events in 2006, whereas avian predators were most frequent in 2008 (Table 2, Fig. 3). Three predation events were not recorded in 2006 because, for unknown reasons, the predator did

not trigger the camera, and four nests were not predated in 2008. Predator composition for real nests was consistent across years, with Arctic foxes responsible for all camera-recorded predation events (Table 2). Only three predation events that occurred at camera-monitored real nests in 2006 and 2007 were not recorded due to poorly positioned cameras (i.e., nest outside of the field of vision).

DISCUSSION

We found that camera monitoring did not appear to affect egg predation rates for Arctic shorebirds, over and above potential observer effects caused by human visitation. When controlling for the spatial, temporal, and behavioral heterogeneity associated with real nests,

Table 2. Relative importance of predators for artificial and real shorebird nests (predators not identified with certainty are noted in parentheses).

	Artificial nests		Real nests		
	2006	2008	2006	2007	2008
Arctic foxes	17 (10)	2	16 (1)	1(1)	2
Long-tailed Jaegers	0	11 (2)	0	0	0
Glaucous Gulls	0	3 (2)	0	0	0
Total	17	16	16	1	2



Fig. 3. Photos of confirmed predators of artificial nests, Glaucous Gull (A), Arctic Fox (B), and Long-tailed Jaeger (C), taken at 5 m, and a photo of the only confirmed predator of real nests, Arctic Fox (D), taken at 15 m. In photos B and D, the fox's snout is located directly in the nest.

the presence of a camera did not affect the risk of predation on artificial nests. Moreover, despite smaller sample sizes, the same conclusion was reached for real shorebird nests, where differences in nest survival between nests monitored with and without cameras were minimal compared to natural interannual variation. The results of our experiments conducted in the open Arctic tundra thus concur with those of most studies conducted in temperate regions and suggest that nest survival is not significantly affected by the presence of cameras (Brown et al. 1998, Thompson et al. 1999, Pietz and Granfors 2000, Keedwell and Sanders 2002, Coates et al. 2008).

Two other studies of the effects of camera monitoring on Arctic-nesting shorebirds produced conflicting results. Cartar and Montgomerie (1985) reported evidence that cameras attracted predators to White-rumped Sandpiper nests, with 8 camera-monitored nests predated and 11 nests without cameras not predated. In contrast, Liebezeit and Zack (2008) reported

that camera monitoring had no effect on nest survival of shorebirds and songbirds nesting in a predator-dense Alaskan oilfield. The camera effect documented by Cartar and Montgomerie (1985) may have been driven by increased human activity around camera-monitored nests because they reportedly changed camera set-ups three times in a 2.5-d period, each time moving the camera closer until they were within 2 m of the nest. In our study, as well as Liebezeit and Zack's (2008), cameras were placed at least 5 m from nests. We tried to control human activity by keeping visit rates equal between nests monitored with cameras and those without. Although our visit rates could have increased nest predation rates (Tulp et al. 2000) and affected our ability to detect camera effects, higher visit rates (if equal across treatments as in our study) were also more likely to increase our ability to detect camera effects because the precision of daily nest survival estimates is greater when intervals between nest visits are short. In addition, even in years with low predation rates

(2007 and 2008), we did not detect an effect of cameras.

Keedwell and Sanders (2002) reported no differences between video-monitored and human-visited nests for a ground-nesting shorebird (Banded Dotterels, *Charadrius bicinctus*) targeted primarily by mammalian predators. However, these authors suggested that sample sizes (limited by the number of cameras) may have been too small to detect differences. Our study of real nests also suffered from relatively small sample sizes, a common problem among many camera-effect studies (Richardson et al. 2009). We tried to remedy this issue by conducting artificial nest experiments in addition to monitoring real nests and are thus more confident in our conclusion of no effect.

Liebezeit and Zack (2008) found that the primary nest predators of shorebird nests were Arctic foxes. Similarly, all predators recorded at real nests in our study were Arctic foxes. Although other types of predators could have been responsible for the three predation events that we failed to detect at real nests, we feel this is unlikely because 100% of the 19 recorded events across all 3 yr were Arctic foxes and we know that avian predators were adequately detected by cameras at artificial nests. The strong annual variation in daily nest survival estimates were thus likely linked to changes in the abundance and behavior of foxes that, at our study site, are influenced by cycles in lemming abundance (Bêty et al. 2001, 2002). Lemming densities were indeed low in 2006, the year with the highest predation pressure, and densities were higher in 2007 and 2008 (G. Gauthier, unpubl. data), the years with lower predation pressure. Such bird–lemming interactions have been documented previously for other shorebird populations (Summers et al. 1998, Blomqvist et al. 2002).

Herranz et al. (2002) reported that artificial Common Wood Pigeon (*Columba palumbus*) nests monitored with noncamouflaged cameras had higher nest survival estimates than nests monitored with either camouflaged cameras or no cameras. These authors suggested that Black-billed Magpies (*Pica pica*), the main predator in their study, were regularly trapped and hunted by humans and thus may avoid conspicuous artificial objects. As also noted by Liebezeit and Zack (2008), we found no evidence of such avoidance by predators in our study area

because camera monitoring had no apparent effect on nest survival even when the relative importance of predators (avian vs. fox) changed between years. Arctic foxes were responsible for all recorded predation events at real nests in 2006 through 2008. However, predators of artificial nests included birds in 2008, possibly because of an increased population of nesting avian predators in that year (G. Gauthier and J. Bêty, unpubl. data). The difference in predators of real and artificial nests further supports our conclusion that cameras did not attract avian predators because these predators were never recorded at real nests during the study, that is, if cameras attracted avian predators we would have expected avian predators at real nests as well. Finally, some cameras located at real nests in our study were visited and marked by foxes (with urine), possibly indicating a potential predator attraction phenomenon. However, the nests were nonetheless left untouched by the predators.

Monitoring nests with cameras provides several possible advantages over visiting nests, including less uncertainty in assigning nest fate and identifying predators. Lariviere (1999) reviewed the numerous problems associated with identifying predators from nest remains and strongly supported camera monitoring as the only viable solution to accurate predator identification. Moreover, nest success for many species may be inferred by the number of membranes in a nest or other signs of hatching, such as small shell fragments (as in shorebirds; Mabee et al. 2006). In general, if a nest is visited and there are signs of hatching and at the next visit the nest is empty, it is often assumed that the eggs successfully hatched and young fledged (as in this study). This, however, may not be the case. In 2008, we monitored several shorebirds nests with cameras. Two of these nests were considered successful based on our observation of at least one hatched chick in the nest and shell fragments found in the empty nest cup the day after chicks were sighted. All evidence pointed to successful hatching of all four chicks, except for photos of an Arctic fox preying the chicks in the nests just hours after hatching. Of course, based on our definition of nest success, these were technically successful nests because the eggs hatched; the young just did not fledge.

Our results, and those of several other studies, indicate that the negative effects of camera

monitoring on nest survival, if any, appear to be minimal relative to the benefits (Cutler and Swann 1999, Thompson et al. 1999, Pietz and Granfors 2000, Keedwell and Sanders 2002, Liebezeit and Zack 2008, Richardson et al. 2009). We were able to detect changes in predator composition between years for artificial nests and confirm the identity of predators for real nests. However, we recommend that investigators considering the use of cameras for monitoring nests proceed with caution, especially in areas with higher predator densities and richness and when working with species of conservation concern. In such cases, we recommend preliminary tests like those in our study, as well as consideration of other potentially important factors, such as camera positioning (distance from the nest) and camera camouflage. If the presence of cameras is determined to have no apparent additional effect on nest survival, above and beyond human monitoring, then the number of nest visits can be reduced or even eliminated to minimize potential disturbance effects.

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