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QUANTIFYING NORTHERN GOSHAWK DIETS USING REMOTE CAMERAS AND OBSERVATIONS FROM BLINDS

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ABSTRACT.—Raptor diet is most commonly measured indirectly, by analyzing castings and prey remains, or directly, by observing prey deliveries from blinds. Indirect methods are not only time consuming, but there is evidence to suggest these methods may overestimate certain prey taxa within raptor diet. Remote video surveillance systems have been developed to aid in monitoring and data collection, but their use in field situations can be challenging and is often untested. To investigate diet and prey delivery rates of Northern Goshawks (*Accipiter gentilis*), we operated 10 remote camera systems at occupied nests during the breeding seasons of 1999 and 2000 in east-central Arizona. We collected 2458 hr of useable video and successfully identified 627 (93%) prey items at least to Class (Aves, Mammalia, or Reptilia). Of prey items identified to genus, we identified 344 (81%) mammals, 62 (15%) birds, and 16 (4%) reptiles. During camera operation, we also conducted observations from blinds at a subset of five nests to compare the relative efficiency and precision of both methods. Limited observations from blinds yielded fewer prey deliveries, and therefore, lower delivery rates (0.16 items/hr) than simultaneous video footage (0.28 items/hr). Observations from blinds resulted in fewer prey identified to the genus and species levels, when compared to data collected by remote cameras. Cameras provided a detailed and close view of nests, allowed for simultaneous recording at multiple nests, decreased observer bias and fatigue, and provided a permanent archive of data.

KEY WORDS: *Northern Goshawk*; Accipiter gentilis; *prey-delivery rate*; *diet*; *remote camera*; *video surveillance.*

CUANTIFICACIÓN DE LA DIETA DE *ACCIPITER GENTILIS* UTILIZANDO CÁMARAS DE VIDEO CON SISTEMA REMOTO DE VIGILANCIA Y OBSERVACIONES DESDE UN ESCONDITE

RESUMEN.—Comúnmente la dieta de las aves rapaces es medida indirectamente por medio de análisis de egagrópilas y restos de presas, o directamente por medio de observaciones de entregas de presa desde un escondite de observación. Los métodos indirectos no sólo toman mucho más tiempo sino que también existe evidencia que sugiere que estos métodos pueden sobre-estimar la importancia de ciertos taxa de presa en la dieta de las rapaces. Se han desarrollado sistemas remotos de vigilancia con cámaras de video para ayudar con la observación y la recolección de datos, pero su uso en situaciones de campo puede ser difícil y en muchos casos no es un método probado. Para investigar la dieta y las tasas de entrega de presa de *Accipiter gentilis*, utilizamos 10 sistemas de cámaras remotas en nidos activos durante las épocas reproductivas de 1999 y 2000 en el centro oriente de Arizona. Recolectamos 2,458 horas de video útil y logramos identificar 627 (93%) restos de presa hasta Clase (Aves, Mammalia o Reptilia). Entre los restos de presa identificados a nivel de género, identificamos 344 (81%) mamíferos, 62 (15%) aves y 16 (4%) reptiles. Durante la operación de las cámaras también hicimos observaciones desde escondites de un subgrupo de cinco nidos para comparar la eficiencia relativa y precisión de los dos métodos. Las observaciones limitadas desde escondites rindieron menos entregas de presa y por lo tanto rindieron tasas de entrega más bajas que la documentada simultáneamente con cámaras. Los datos obtenidos mediante observaciones desde escondites indicaron una habilidad reducida de este método

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para identificar presas a nivel de género y especie al ser comparados con los datos colectados de los videos de las cámaras remotas. Las cámaras produjeron una vista detallada y cercana de los nidos, permitieron la grabación simultánea de varios nidos, redujeron el sesgo y la fatiga del observador y produjeron un archivo permanente de datos.

[Traducción del Equipo Editorial]

Information on diet is important in understanding aspects of avian ecology such as diet overlap among species, predation, and prey selection (Rosenberg and Cooper 1990, Redpath et al. 2001). Diet assessment in raptors is usually done indirectly, by recovering pellets and prey remains, or directly, by observing prey deliveries from blinds; however, accurate estimates of raptor diet can vary depending on the technique employed (Marti 1987).

Indirect diet assessment can provide quantitative and qualitative information because raptors often leave behind undigested remnants of bones, feathers, and keratinous material as pellets, or as prey remains (Reynolds and Meslow 1984, MacLaren et al. 1988, Steenhof and Kochert 1988, Boal and Mannan 1994). However, prey remains and pellets may bias the representation of certain prey items (e.g., bird feathers are more easily detected than small bones); therefore, avian prey may be overrepresented in raptor diet (Simmons et al. 1991, Bielefeldt et al. 1992). Marti (1987) suggested that pellet analysis is accurate only for raptor species that swallow their prey whole. Loss of prey remains to scavengers, investigator disturbance in the nesting area, and miscounting of remnant and incomplete remains may also bias or limit results.

Direct observation of raptors is a more accurate method for investigating diet in species that do not swallow their prey whole. Observations can be made from a blind within the nesting area; however, observations near nests can disturb hawks, are labor intensive and require dawn to dusk observations to obtain complete samples. In addition, direct observation requires positioning of the blind so that a view inside the nest bowl is possible (Collopy 1983).

A more recent technology for studying diet involves remote cameras at raptor nests (Ouchley et al. 1994, Booms and Fuller 2003, Lewis 2004a). Advantages of video surveillance for measuring diet include a reduction in observer bias and fatigue, minimal impact on an animal's behavior, detailed information on diet composition, and an archival record of footage (Kristan et al. 1996, Stewart et al. 1997, Delaney et al. 1999). Lewis et al. (2004b) compared three methods for assessing raptor diet: video recording, pellet analysis, and prey remain analysis. They found that quantifying prey using either prey remains or pellet analysis did not provide as complete a description of diet when compared to remote cameras. They did not, however, compare observations from blinds to remote cameras. In this paper, we describe a camera system, monitoring, and data collection using remote video technology, and discuss advantages and disadvantages. In addition, we conducted limited observations from blinds at five nests and simultaneously collected data with remote cameras to compare the two methods.

STUDY AREA

We conducted this study on the Sitgreaves portion of the Apache-Sitgreaves National Forest in east-central Arizona. The Sitgreaves portion encompasses ca. 350 800 ha (elevation = 1768–2417 m) and is located atop the Mogollon Rim on the southern edge of the Colorado Plateau. The Mogollon Rim is a large glacial escarpment that extends east across central Arizona into New Mexico. The Mogollon Rim edge has deep drainages with mixed-conifer communities of Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), trembling aspen (*Populus tremuloides*), ponderosa pine (*Pinus ponderosa*), New Mexican locust (*Robinia neomexicana*), and Gambel oak (*Quercus gambelii*; Brown 1994). Ridgetops are dominated by ponderosa pine forest.

METHODS

We chose video monitoring as the primary method to quantify the diet of breeding Northern Goshawks (*Accipiter gentilis*) in east-central Arizona (Rogers et al. in press). During the breeding seasons of 1999 and 2000, we randomly selected 10 nests (four in 1999 and six in 2000) from a pool of known territories (N = 48). During June 1999 and 2000, we mounted EOD-1000 Electro-optics® remote cameras (Electro-Optics, St. Louis, MO U.S.A.) when nestlings were between 4–7 d old (nestlings were shaded during camera installation). Cameras ran from 22 June–18 July 1999 and 6 June–31 July 2000. We needed a minimum of three people for camera placement with a mean setup time of 110 min per nest (range = 80–132 min). Nest trees were ponderosa pine or Douglas-fir, and nest heights were ca. 20 m above ground.

Cameras were 3.5 × 12 cm and equipped with 3.6 mm lenses. Each camera had 380 lines of resolution and a one-lux digital color system. During installation, the ground crew viewed the nest using a Broksonic D.C. TV/VCR combination (Broksonic Corporation of America,

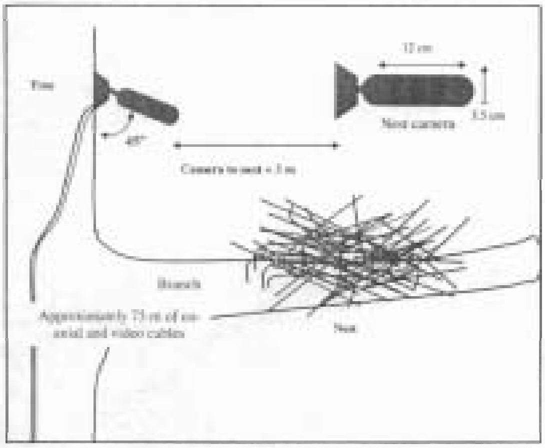

Figure 1. Schematic of camera system for monitoring Northern Goshawk nests in east-central Arizona in 1999 and 2000.

New York, NY U.S.A.) while a person in the nest tree positioned the camera. Once positioned, we secured the camera to the trunk of the tree or an overhanging branch. The goal in camera placement was a field of view that contained the entire nest structure and focused on the nest bowl. This was achieved by positioning cameras about 3 m away from nests at about a 45° angle to the nest structure (Fig. 1). Cameras were connected to 75 m of durable telephone-power cord and coaxial video cable (copper coated RG-59) tacked along the trunk of the tree. Camera cords were attached to a Panasonic® AG-1070 DC (Panasonic, Secaucus, NJ U.S.A.) or Sony® SVT-DL224 (Sony, Park Ridge, NJ U.S.A.) time-lapse VHS recorder, which were placed at least 50 m from the nest tree. Both time-lapse VCR models were industrial grade, 12-volt DC models with time-lapse programming capability. VCRs were housed in military ammunition cans (20 mm) and powered by one 12-volt, 64 amp-hr sealed Optima® (Optima, Denver, CO U.S.A.) rechargeable lead acid battery (22 kg each). Batteries were kept dry under a plastic bin. Ammunition cans were locked, and all ground equipment was secured to a tree. Finally, we covered equipment with forest litter for shade and camouflage. Cost for one complete system was about $1470 US (Table 1).

We programmed VCRs to record 5 frames/sec, which provided up to 24 hr of footage per videotape. We recorded activity at each nest in a 2-d sequence (12 hr/d), and cameras recorded 6 of 7 d of the week. We recorded from 0450–1650 H on day one and 0800–2000 H on day two. During 1999, all batteries and tapes were changed at night to reduce disturbance to hawks. In 2000, battery and tape changes occasionally occurred before nightfall, but only if ground equipment was located out of sight of nests. No more than 5 min were spent within nest stands changing batteries and tapes every other night or day. We continued to record video at nests until fledgling Northern Goshawks did not receive prey deliveries for 2 consecutive days.

Table 1. Cost of video surveillance equipment used for a diet study of Northern Goshawks in Arizona during breeding seasons 1999 and 2000. Prices based on 1999 retail costs associated with assembly of one system.

COMPONENT	APPROXIMATE COST ($ US)
VHS time-lapse recorder[a]	675
Remote video camera	250
DC television monitor	190
Rechargeable battery	180
2-amp battery charger[b]	85
Coaxial and power cables and connectors	80
50 caliber ammunition can/locks and cables	50
Total	1470

[a] Cost of Panasonic and Sony VHS recorder were averaged (Panasonic = $810.00/Sony = $520.00).

[b] TV/VCR combo used for multiple units.

We viewed video footage on a 19 in Toshiba® television (Toshiba, Irvine, CA U.S.A.) with a JVC® SuperVHS VCR (JVC, Wayne, NJ U.S.A.). Prey items were identified to Class (Mammalia, Aves, or Reptilia), genus and species when possible, or classified as unknown. Prey items identified to class only were characterized as small, medium, or large based on *a priori* size class categories from Cockrum and Petryszyn (1992) and Dunning (1993).

To compare methods, we observed goshawks (2000 breeding season) at a subset of five nests from blinds constructed 25–40 m from nests. We erected blinds on ground prior to sunrise before each observation period. Blinds were constructed of camouflage heavy-duty canvas with screen windows in all directions, which allowed for observation of hawks within the immediate nesting area. We used 8 × 32 binoculars and a 20 × 60 spotting scope to count and identify prey items delivered to nests. Items were identified to Class (Mammalia, Aves, or Reptilia) and to genus and species when possible. We initiated blind observations when nestlings were between 8–12 d old and continued observing prey deliveries until young fledged. We conducted observations in 3–4 hr blocks each day starting at sunrise, and blinds were disassembled upon completion of each observation period. We allowed a 20-min acclimation period for adults and young before beginning observation. Observations from blinds were done in conjunction with video monitoring to compare accuracy of the two methods. In addition, observations from blinds and video reviewing were done by one person (Rogers) to minimize bias.

RESULTS

Camera Results. Adult Northern Goshawks actively defended the nest while we placed cameras in nest trees. However, adult females returned to the nest within 10–20 min after we vacated territories, as documented from video. In addition, we had no nest abandonment due to camera presence, and eight of 10 nests were successful (i.e., fledged ≥1 young). One nesting attempt failed due to adult female mortality (Bloxton et al. 2002), and one was depredated by a Great Horned Owl (*Bubo virginianus*). Adults did not flush during nighttime battery and tape changes. Adults flushed infrequently during daytime changes because we were out of sight of the nest tree.

We collected 2458 hr of usable video footage, and about 500 hr were spent viewing tapes to identify and quantify prey items. Approximately 50 hr were spent changing batteries and tapes, excluding travel time. We documented 676 prey deliveries from camera footage. Of these, we identified 627 (93%) prey items to Class (Aves, Mammalia, or Reptilia) and observed a mean delivery rate of 0.28 (SE = 0.02) prey items/hr. We were able to identify, at least to genus, 422 (62%) of all prey items. Of items identified to at least genus, 344 (81%) were mammals, 62 (15%) were birds, and 16 (4%) were lizards.

Direct Observations. Because blinds were constructed before sunrise, adults infrequently flushed from nests. However, during disassembly and exiting nest territories, adults actively defended nests. When adults did flush from nests prior to an observation period, they returned to the nest within about 10 min. We observed goshawks for a total of 43 hr at five nests. We viewed seven prey deliveries, all of which were identifiable to Class. Mean prey delivery rate observed from blinds was 0.16 (SE = 0.06) items/hr.

Camera Versus Direct Observation. Camera footage yielded a higher total number of prey items delivered; therefore, our estimated prey delivery rate derived from video footage was higher than that derived from direct observation. An important result was that the camera footage revealed 12 deliveries during our observation period in which we visually documented only seven deliveries. Accuracy of prey identification to class was 100% using both methods, but we were able to document 58% of all prey to genus and/or species from the video footage compared to 0% from direct observations.

DISCUSSION

Use of remote camera systems is becoming a popular technique in wildlife studies, especially as equipment costs decrease. For example, the video surveillance equipment used in Lewis et al. (2004a) was over $2000 US and did not include batteries and chargers. Our equipment was similar to Lewis's, but the cost was $1470 US, which included batteries and chargers.

Cameras have been used to monitor diet, predation events, and various behaviors of many species of wildlife (e.g., Wisniewski 1983, Sykes et al. 1995, Hughes and Shorrock 1998, King et al. 2001). Responses to camera installation may vary by species and individuals, timing of camera placement during the nesting season, and length of time needed for camera installation. Several workers reported no sign of nest abandonment due to cameras (Estes and Mannan 2003, Booms and Fuller 2003, Lewis et al. 2004a). However, Cain (1985) reported nest abandonment by Bald Eagles (*Haliaeetus leucocephalus*) due to camera installation. During our study, goshawks were distressed when cameras were installed, but did not seem to be affected by camera presence. In videos, adult and juvenile goshawks occasionally could be seen looking up at cameras, and there were several occasions when hawks perched directly below or on cameras. Goshawks were also distressed during our observations from blinds, especially during our exit from territories, which suggested that direct observations were more stressful to the nesting hawks than use of cameras.

Remote cameras can facilitate sampling for extended periods of time with a reduction in observer bias (Delaney et al. 1999). In contrast, observations from blinds are often done by more than one person, which increases the risk of observer bias (Boal and Mannan 1994). Video monitoring can also increase daily coverage because unmanned units can operate continuously. For example, we were able to collect nearly 2500 hr of observations in 2 yr with 10 cameras, whereas Boal (1993) and Boal and Mannan (1994) collected 1500 hr of observation from blinds, which required three field assistants per year for 3 yr. Observer fatigue could also bias the results based on direct observation, and the cost of labor would be high.

Using remote cameras, we were able to record prey deliveries at the nest for up to 1 mo after Northern Goshawk young fledged (Rogers et al. in press). In contrast, observations from blinds and pellet and prey remains collection are often discontinued shortly after young fledge (MacLaren et al. 1988, Seguin et al. 1998). Although prey delivered to nests during branching and fledgling stages often occurred out of camera range, allowing

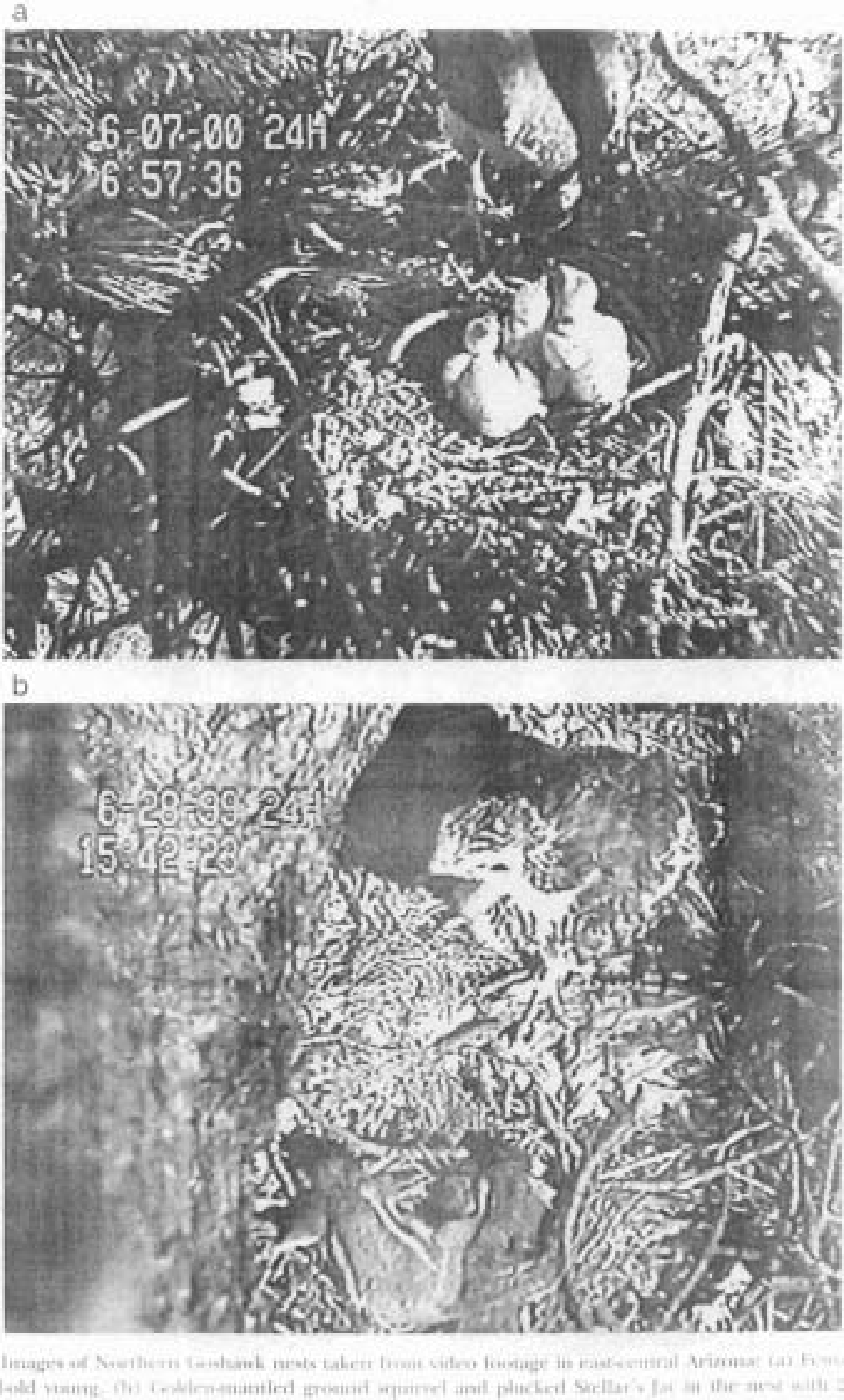

Figure 2. Images of Northern Goshawk nests taken from video footage in east-central Arizona: (a) Female goshawk feeding 5-d-old young. (b) Golden-mantled ground squirrel and plucked Stellar's Jay in the nest with 25–30 d old goshawk young.

cameras to operate longer provided additional qualitative information on post-fledgling diet. Additional advantages of cameras include decreased frequencies of observer entrances and exits within territories. We spent no more than 5 min in nest stands every other day and usually did not flush adults from nests. We strongly recommend changing batteries and tapes at night, or alternatively locating ground equipment 50 m or more from nest trees.

Most importantly, using remote cameras greatly increased our ability to identify genus and species of prey delivered to nests. With cameras, we were able to see shape and color of most prey items (Fig. 2). Mammals were easiest to identify to genus and species due to their size and distinctive pelage, as well as the ability to see feet and tails. Small birds were the most difficult to identify, but the ability to see feathers, and hence make an identification, distinctly increased if the adults plucked avian prey in the nest.

Our data indicated that observations from blinds resulted in underestimates of prey numbers and delivery rates, but this needs further investigation. Prey items were missed in two ways during observations from blinds. First, on some occasions we failed to notice small prey items brought by the female because we were focusing on identifying an item brought previously by the male. Second, we missed some prey items that were delivered to nests after dark or prior to daybreak. We did not use these items in calculating prey delivery rates, but included them in total prey deliveries. Without the ability to play back the videotape, we would not have noticed these prey items.

A final advantage of video monitoring was the ability to record infrequent behavioral events. For example, during the 1999 nesting season, we documented an attempted predation by a Red-tailed Hawk (*Buteo jamaicensis),* and in 2000, we recorded a bobcat (*Lynx rufus)* scavenging prey from a nest that had already fledged young.

There are some limitations and constraints to using camera systems. We experienced technical difficulties including rodent and ungulate damage to cords, battery failure, loose connections, and water damage. In addition, when cameras' angles were >45° to the nest, the view was often obstructed by the adult female's back. To alleviate this problem, we searched for alternative branches or nearby trees that allowed for a 45° angle to the nest bowl. We recommend placing cameras opposite the direction of the adult flight pathway to the nest. Therefore, observing adult movement patterns near nests before camera placement is recommended. Video monitoring involves a relatively high initial cost. Also, as of 2000, no audio capability was available within a waterproof system. Thus, collecting data on vocalizations during prey deliveries was not possible. One additional disadvantage of video technology is the additional time required to transcribe video data. Even though tapes were fast forwarded during non-prey delivery times, it took ca. 1 hr of viewing to transcribe data for every 5 hr of video footage collected. We suggest viewing collected tapes daily to minimize backlog and to allow researchers to become aware of system problems before data collection is complete.

In conclusion, we think remote cameras allowed us to collect more accurate diet data than if we would have solely used blind observations. Camera-monitoring systems are efficient, relatively noninvasive tools for quantifying diet and behavior of raptors.

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