ORNITOLOGIA NEOTROPICAL 15 (Suppl.): 467–476, 2004

NEST MANAGEMENT FOR THE PUERTO RICAN PARROT (*AMAZONA VITTATA*): GAINING THE TECHNOLOGICAL EDGE

Thomas H. White, Jr.[1] & Francisco J. Vilella[2]

[1]U.S. Fish and Wildlife Service, Puerto Rican Parrot Recovery Program, Box 1600, Rio Grande, Puerto Rico 00745. *E-mail*: diputado99@hotmail.com

[2]U.S.G.S. Biological Resources Division, Cooperative Fish and Wildlife Research Unit, Box 9691, Department of Wildlife and Fisheries, Mississippi State University, Mississippi State, MS 39762 USA. *E-mail*: fvilella@cfr.msstate.edu.

Resumen. – Manejo de nidos de la Cotorra Puertorriqueña (*Amazona vittata*): implementando tecnología de punta. – El manejo de la Cotorra Puertorriqueña (*Amazona vittata*) desde 1973 ha incluido esfuerzos para incrementar el éxito reproductivo a través del mejoramiento de cavidades naturales, uso de nidos artificiales y vigilancia intensa de la actividad reproductiva con intervención activa. A pesar de que estas prácticas han aumentado el éxito reproductivo comparado el con manejo pasivo en el pasado, la aplicación reciente de técnicas de monitoreo electrónico ha incrementado tanto el éxito reproductivo como nuestro conocimiento sobre la ecología y el comportamiento de nidificación de la especie. Estas nuevas técnicas incluyen monitoreo audiovisual de nidos activos, permitiendo la documentación precisa de actividades reproductivas, así como la detección temprana de problemas potenciales con mínima perturbación a la pareja reproductiva. En este trabajo discutimos el diseño, costos e implementación de este sistema de monitoreo. También resumimos los beneficios obtenidos y la aplicabilidad de esta tecnología en estudios sobre la historia natural y el manejo de poblaciones para otras especies de aves que utilizan cavidades en bosques y selvas Neotropicales.

Abstract. – Management practices for the critically endangered Puerto Rican Parrot (*Amazona vitatta*) since 1973 have included proactive efforts to increase nesting success through improvement of natural nest cavities, placement of artificial nest cavities, and close monitoring of nesting activity and active intervention. While these practices have resulted in improved overall nesting success over previous passive management, recent application of electronic monitoring techniques has increased not only nesting success, but also knowledge of the nesting and behavioral ecology of the species. These new techniques include both audio and video monitoring of active nest cavities, allowing for accurate documentation of nesting activities and early detection of potential problems with minimal disturbance to the nesting pair. Herein we discuss design, costs, and implementation of these monitoring systems. We also summarize the benefits accrued to date, as well as the transferability of these readily available, and user-friendly, technologies in natural history studies and population management of other cavity-nesting species in Neotropical forests. *Accepted 12 January 2004*.

Key words: *Amazona vittata*, audio, infrared, management, monitoring, nesting, Puerto Rican Parrot, video camera.

INTRODUCTION

Acquiring reliable data on reproductive ecology is of fundamental importance in the study and management of endangered species. Amongst avian species, cavity-nesters present special challenges because of extended nesting phenology, heightened parental attentiveness and sensitivity to disturbance, and secretive behavior of breeding pairs when in proximity to their nest cavity (Skutch 1957, Ligon 1970, Lanning & Shiflett 1983, Snyder *et al.* 1987, Grenier & Beissinger 1999). In the Neotropics, these challenges are frequently compounded by structurally complex habitats and intractable environmental conditions. Because of these inherent difficulties, biologists often go to great, even dangerous lengths attempting to collect the data necessary to effectively study and manage endangered, or otherwise little-known, populations of Neotropical cavity-nesters (Lanning & Shiflett 1983, Renton & Salinas-Melgoza 1999, Brightsmith 2000, Morera 2001, Pinho & Nogueira 2003).

Such is the case with the Puerto Rican Parrot (*Amazona vittata*), once abundant throughout Puerto Rico and it's major satellite islands (Snyder *et al.* 1987). Primarily because of past habitat loss, this critically endangered endemic species is currently restricted to the montane rainforest of the Luquillo Mountains in northeastern Puerto Rico, where a small relict wild population has been under intensive management since 1973 (Wiley 1981, Snyder *et al.* 1987). Numbers in the wild have remained low, ranging annually from approximately 13–50 over the past 30 years (Snyder *et al.* 1987, USFWS 1999), making the Puerto Rican Parrot one of the ten most endangered birds in the world (USFWS 1999).

Many of the challenges to Puerto Rican Parrot recovery are common to other endangered Neotropical cavity-nesters, particularly Psittacines. Among these, nest failure has been identified as a major limiting factor to population growth (Snyder & Taapken 1977, Snyder *et al.* 1987). Accordingly, management practices for the wild Puerto Rican Parrot population have consisted mainly of proactive efforts to maximize reproductive success. Efforts have included locating and improving natural nesting cavities, placement and maintenance of artificial cavities made of PVC (polyvinyl chloride), and intensive monitoring of nesting activity from observation blinds combined with active intervention as necessary (Wiley 1985, Snyder *et al.* 1987, Lindsey 1992, USFWS 1999). These measures have resulted in improved nesting success, compared to previous passive management (Snyder *et al.* 1987, Lindsey 1992, USFWS 1999). However, continuing challenges to such efforts include difficult access to some nest cavities, secretive behavior and sensitivity to disturbance by nesting pairs, and inherent difficulties of monitoring the status of clutches and nestlings. Recent developments in electronic technology have provided tools to successfully resolve some of these difficulties associated with the study and management of cavity nesters (e.g., Proudfoot 1996, King *et al.* 2001, Stake & Cimprich 2003). Here, we present unique technological applications that have aided in overcoming some of the challenges to wild nest management for the Puerto Rican Parrot, and we discuss the potential application of these technologies in natural history studies and population management for other Neotropical cavity-nesting species. Our objective was to evaluate the utility of an audiovisual nest monitoring system for obtaining reliable nesting data, which may be used for timely management decisions.

STUDY AREA AND METHODS

All wild nest management activities for the Puerto Rican Parrot were conducted in the Luquillo Mountains, also known as the Caribbean National Forest or Luquillo Experimental Forest, located in northeastern Puerto Rico (18º18'N, 65º47'W). This mountainous forest reserve encompasses 19,650 ha of subtropical rainforest ranging in elevation from 200 m to 1074 m above sea level. However, Puerto Rican Parrot nesting areas are located at elevations from 500 m to 700 m, corresponding to the palo colorado (*Cyrilla racemiflora*) and tabonuco (*Dacryodes excelsa*) forest types. Palo colorado is the primary tree species used for nesting. Annual precipitation ranges from 200 cm in the foothills to over 500 cm at the highest peaks (Snyder *et al.* 1987). Annual temperatures range from 11° to 32°C, averaging 21°C (Lindsey 1992).

Locating and monitoring wild nests. At the onset of breeding season (Jan.–Feb.), active nests of wild Puerto Rican Parrots have typically been located by monitoring parrot activities from canopy-level (25–35 m) observation platforms, followed by ground reconnaissance to locate the actual nest tree. Because successful nests tend to be reused for several years, long-term monitoring is possible once an active nest has been discovered. Repeated use of successful nests is common among many cavity-nesters (Brush 1983, Ingold 1991, Sedgwick 1997), particularly Psittacines (Saunders 1982, Snyder *et al.* 1987, Forshaw 1989, Gnam 1991, Morera 2001, Pinho & Nogueira 2003). Permanent observation blinds have been constructed at all known active nest sites to facilitate diurnal nest monitoring (Lindsey 1992). Only three to six nests are active in any given year since intensive recovery efforts began (USFWS 1999). Active nests are monitored to obtain data on individual and overall nesting success, and to allow timely intervention in situations in which nest failure is imminent. Such situations have included nest predation attempts by Pearly-eyed Thrashers (*Margarops fuscatus*) and Red-tailed Hawks (*Buteo jamaicensis*), flooding of nests by rainwater, honeybee (*Apis mellifera*) swarm infestations, botfly (*Philornis pici*) parasitism of nestlings, and occasional episodes of nest abandonment during incubation or brooding (Snyder & Taapken 1977, Wiley 1985, Snyder *et al.* 1987, Lindsey 1992, Wilson *et al.* 1997, USFWS 1999).

Audio monitoring. Initial nest monitoring efforts relied on constant visual observation and observer attentiveness to parrot activities at or near the nest entrance (Snyder *et al.* 1987, Lindsey 1992). This type of monitoring was taxing on observer concentration and attention spans, and also relied heavily upon observer experience for interpretation of behavioral patterns of nesting Puerto Rican Parrots to avoid the false perception of potential problems (Lindsey 1992; Wilson *et al.* 1995, 1997). Moreover, acquisition of reliable data on activities within nests was virtually impossible without climbing the nest tree and physically inspecting the nest cavity, potentially disrupting the nesting pair and causing temporary or permanent nest abandonment (Snyder *et al.* 1987, Wilson *et al.* 1995). In 1989, a small electronic microphone was experimentally installed in each active nest and connected to a battery-powered speaker located in the observation blind (Wilson *et al.* 1995). These microphones allowed observers not only to more reliably document ingress and egress of nesting adults, but also to gain more accurate estimations of hatching dates and determinations of hatchling presence and activity. Moreover, potential problems inside nests could be detected sooner because the actual adult and nestling vocalizations could be clearly heard, including other sounds indicative of honeybee or botfly presence in the nest cavity.

Subsequent years showed increased numbers of Puerto Rican Parrots fledging in the wild (USFWS 1999), attributed in part to increased efficacy of nest management aided by microphones (Vilella & Arnizaut 1994, Vilella & Garcia 1995). Microphones also reduced the number of routine physical nest inspections required, reducing danger to field personnel from frequently climbing tall, and often slippery, trees to access the nest cavity. The success of this modification led to standard use of microphones in all subsequent

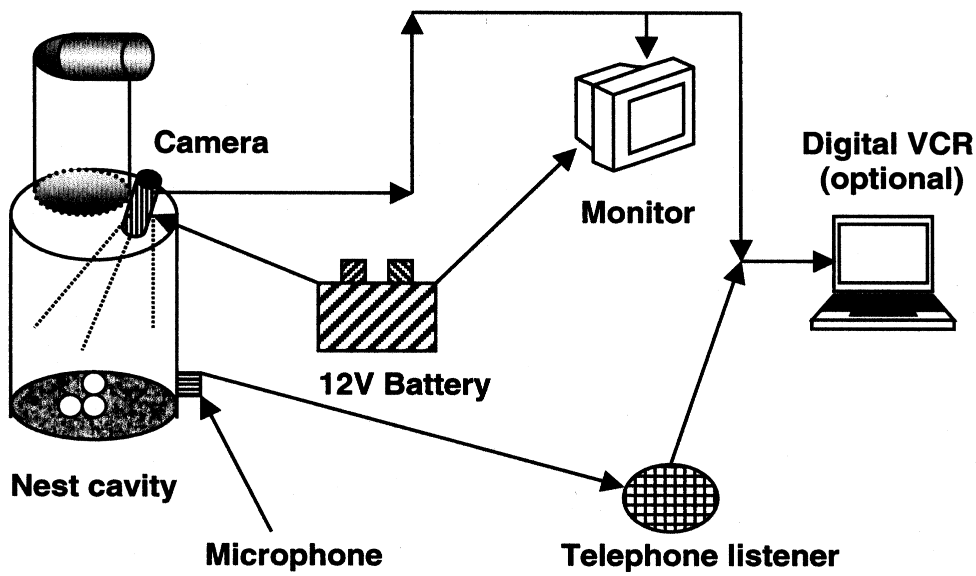

FIG. 1. Schematic diagram of the audiovisual nest monitoring system developed for Puerto Rican Parrot nests.

wild Puerto Rican Parrot active nests (USFWS 1999).

Video monitoring. Shortly before onset of the year 2003 breeding season, we choose two of the most frequently used artificial PVC nest cavities (SF2-A, SF2-B) for experimental installation of 12V-DC-powered closed-circuit infrared (IR) video cameras. Cameras were installed by drilling a 38 mm diameter hole into the nest cavity through which the cylindrical camera body was inserted (Fig. 1). The camera-mounting base was secured to the exterior of the nest cavity using screws and the hole sealed with opaque silicone sealant. All external surfaces were then sprayed with a non-reflective paint to camouflage the installation. Nest microphones were installed similarly via a 10 mm diameter hole into the nest cavity. For natural cavities, both the camera and microphone can also be installed within a 50 mm inside-diameter PVC pipe of sufficient length to access the inside of the nest chamber via a hole drilled from the outside. Both the camera and nest microphone were connected to a videocassette recorder (VCR) unit located in the observation blind, thus combining audio and video monitoring and recording in a single application (Fig. 1).

Each video monitoring system featured a Marshall Electronics (El Segundo, CA USA) V-1214-IR weatherproof "bullet" camera with integral infrared emitters and a 3.6 mm auto iris lens. The built-in infrared capability allows image acquisition in total darkness at distances to 4.6 m. Cameras operated on 9–16 V-DC at 110mA and were powered by either a marine deep-cycle 12V battery or a portable Panasonic® LCR12V7.2P rechargeable battery pack. We used a portable Sony® GV-D800 Digital 8 VCR powered by a Sony® NP-F960 rechargeable battery for both monitoring and video recording, and we alternated VCR use between both observation blinds. We also installed a ProVideo® (CSI, Amityville, NY) VM-401W 12V-DC monochrome monitor in one observation blind (SF2-A) for monitoring purposes when not using the VCR. For audio capability, we used Radio Shack® 330-3028 1.5V-DC omni-directional microphones connected to Radio Shack® 430-0231C 9V-DC portable telephone listeners in the observation blinds. The telephone listeners were modified by addition of an output line to combine the audio and video signals for recording by the VCR (Fig. 1).

On nest observation days, the monitoring system was activated upon entering the observation blind, and remained on for the duration of the observation period. Although video monitoring of the nest interior was continuous, recording with the VCR occurred intermittently depending upon actual parrot presence and nesting activities. For recording, we used metal Hi8 MP videocassettes for maximum image quality.

In evaluating benefits of the monitoring system, we compared relative amounts of qualitative observational information obtained during the preceding two nesting seasons (2001, 2002), when no cameras were used, with the 2003 season for the two camera-equipped nests. Each nest was active during each of the three years. Nest monitoring protocol also was the same during each of the three years. Further, nesting pairs were the same for each nest during both 2002 and 2003, based on leg bands and plumage characteristics. For comparative purposes, we broadly categorized qualitative observational information as: 1) monitoring efforts and attendant nest inspections, 2) detection times for eggs and hatchlings and, 3) behavioral observations of nestlings and adults, including brooding activities and fledging attempts.

RESULTS

Monitoring efforts and nest inspections. We accumulated 418 h of monitoring time during 86 observation periods at the two camera-equipped parrot nests during the 2003 nesting season, of which 31.5 h were recorded on videotape. For these two nests, total number of observation periods during 2001 and 2002 were 82 and 98, respectively. Total monitoring times for these same nests during years 2001 and 2002 were 336 h and 367 h, respectively. For both camera-equipped nests, there were a combined total of 16 physical nest inspections during 2003. These inspections, accomplished via an access door to the nest chamber, were performed to accomplish various tasks such as monitoring chick development, inspecting chicks for botfly larvae, banding nestlings, changing nest material, collecting blood samples, and attaching radio-transmitters to nestlings.

During the 2001 and 2002 seasons, these two nests were inspected on 19 and 16 occasions, respectively. However, during 2001 and 2002, 10 additional inspections were attempted to ascertain presence and numbers of eggs or nestlings, but field personnel were unable either because of attentiveness by the nesting pair, or uncertainty as to whether the nesting female was inside the cavity. Additionally, two of the inspections later proved unnecessary. These two inspections were prompted by unidentifiable sounds originating from within the nest cavity. Upon inspection, no cause of the sounds was detected. In contrast, during 2003, physical nest inspections were performed only as required for handling nestlings or changing soiled nest material. Moreover, we were able to positively confirm presence/absence of nesting females within nests before inspection attempts, thereby avoiding inadvertent disturbance of nesting pairs. In fact, because each video monitoring episode constituted a "nest inspection", we actually conducted a combined total of 86 inspections for the two nests during 2003. These additional inspections represented an approximate fivefold increase (i.e., 86 vs 16–19) in total observational intensity compared to years before cameras were deployed.

During April 2002, one of the nests failed when the two nestlings died at 7–9 days of age, apparently from botfly larvae infestation. Two previous attempts to inspect the nest were thwarted, by close parental attentiveness in one instance, and observer uncertainty as to nest occupancy by the female in the other. When finally inspected, one nestling was found dead and the other moribund. Although we cannot be certain an earlier nest inspection would have prevented the loss, the earlier such problems are detected, the greater the chances of successful remedy. Furthermore, as only 4 wild nestlings were produced in 2002, this loss amounted to half the total wild productivity for that nesting season.

On 10 March 2003, while using the video monitor, a nest observer was alerted to an apparent nest predation attempt by a Pearly-eyed Thrasher. This occurred when the observer noticed the nestlings assuming a defensive posture within the nest. Upon investigation, a thrasher was discovered to have surreptitiously entered the nest entrance. The observer chased off the thrasher and no injuries occurred to the nestlings.

Detection times. Detection time was the estimated number of days elapsed prior to documentation of eggs or hatchlings within the nest. For both nests during 2001 and 2002, detection time for eggs averaged 9 days (range 4–20 days). For hatchlings, detection time averaged 2 days (range 1–3 days). Hatchlings were more rapidly detected, as their vocalizations could be heard via microphones. During the camera-equipped 2003 season, detection times were equal to, or less than 1 day in all cases, with actual hatching of eggs observed in some instances. Thus, the audiovisual monitoring system allowed us to document accurately clutch initiation dates, clutch sizes, hatching dates, and hatchling numbers without disturbing hatchlings or nesting pairs.

Behavioral observations. With any cavity-nesting species, accurate data on behavior and interactions of nestlings and adults inside the nest are extremely difficult to obtain. During the year 2003 nesting season, we directly observed and recorded such behaviors. For example, simultaneous bi-parental feeding of nestlings by Puerto Rican Parrots, long suspected but never directly observed (Snyder *et al.* 1987, Wilson *et al.* 1995), was recorded on videotape during 2003. Further, we used this technological advantage to answer some key questions regarding an important component of our ongoing research efforts: radio-telemetry of wild fledglings. Since year 2000, we have been routinely attaching radio-transmitters to wild nestlings prior to fledging in order to monitor juvenile movements and survival. One of the major assumptions of survival studies is that the mark (e.g., radio-transmitter) does not alter behavior of the marked animals. In radiotelemetry studies, this assumption implies the transmitter attachment does not alter behavior of the nestlings nor interfere with normal interactions between nestlings and parents (e.g., allofeeding, allopreening). In most avian telemetry studies, these important assumptions are never tested because the required observational data are unobtainable. Failure to test these assumptions can confound cause-specific assessments of post-fledging mortality by ignoring potential effects of pre-fledging instrumentation and result in biased parameter estimates (see Lindsey *et al.* 1994, Renton 2001). Using the audiovisual monitoring system, we observed that wild Puerto Rican Parrot nestlings responded initially to transmitter attachment either by attempting to preen the antenna, or attempting to "shake off" the transmitter. Frequency and intensity of these responses gradually waned throughout the first day, and by the second and third day following instrumentation the nestlings appeared oblivious to the devices. More importantly, brooding adults immediately fed all instrumented nestlings upon entering the nests, and exhibited no apparent reaction to the transmitters. Furthermore, direct observations of pre-fledging behaviors (e.g., wing-flapping, climbing) of instrumented nestlings indicated no apparent adverse effect of transmitters.

We did not observe reactions by parrots to the cameras' infrared emitters as the wavelength may be beyond their detection abilities. Because the cameras were activated only during the observation periods, we were able to see and record responses of nestlings and adults upon camera activation. There were no signs that the infrared emitters affected behavior of the nest occupants, or that the parrots were aware of camera activation.

Monitoring system cost and operation. Although total cost of any electronic monitoring system depends upon specific components used, we present the cost of our system as a general guide. All prices are in United States dollars ($USD) and were current as of 2003. The cost of the V-1214-IR cameras was $219.00 each. Each camera comes equipped with 18.3 m of weatherproof 75-ohm RG-59U miniature coaxial cable, though additional cable can be purchased from most electronics suppliers at approximately $1.50/m. The model #330-3028 battery-powered audio microphones were purchased for $29.95 each. Model #430-0231C telephone listeners also cost $29.95 each. The VM-401W monochrome monitor cost $189.95. Although prices vary widely for marine 12V batteries, most can be purchased for under $50. The most expensive item was the GV-D800 video recorder at $730. Miscellaneous supplies (electrical tape, silicone sealant, spray paint) added approximately $6.50 to overall costs. Therefore, total cost for a complete monitoring and video recording system as deployed was $1065.40. However, using these same components, a complete nest monitoring system (camera, microphone, monitor, batteries) can be assembled for approximately $500 without recording capabilities.

Operation and maintenance of the monitoring system was simple. The camera, microphone and telephone listener were activated upon entering the observation blind, and the video and audio cables were then connected to the line inputs of the VCR or monitor. All equipment was turned off at the end of each monitoring session to conserve battery power. Because of the low current drain (110 mA) of the IR cameras, a single fully charged marine battery provided up to 170 h of monitoring time. The NP-F960 video recorder battery pack yielded approximately 7.9 h of monitoring time per charge. Although the VCR was removed from the blind and the battery recharged after each monitoring session, use of a waterproof housing (e.g., Pelican Case®) and extra battery for the VCR could allow for less frequent removal. Batteries for the microphones (1.5V) and telephone listeners (9V) were replaced as needed, usually biweekly.

DISCUSSION

The audiovisual nest monitoring system represented a significant improvement in wild nest management for the Puerto Rican Parrot. The system is simple, reliable, economical, and specifically designed for cavity nests in humid tropical forests. The IR cameras and audio microphones functioned flawlessly even with constant exposure to high humidity and frequent rain. Although King *et al.* (2001) reported development of a wireless video monitoring system, their system requires more open forest conditions, multiple 12V battery-powered transmitting and receiving units for video signals, and substantially greater costs and maintenance than our system. Further, the system of King *et al.* (2001) had no audio capability. With our audiovisual monitoring system, we acquired detailed nesting data reliably and safely and with minimal maintenance. Moreover, uncertainties due to individual observer experience were minimized with this system. Reducing uncertainties in management decisions also reduces tactical errors that can adversely impact individual nest success.

With critically endangered species such as the Puerto Rican Parrot, success or failure of individual nesting attempts can have population-level impacts on species recovery. The loss of a single nest comprising 50% of the year 2002 wild Puerto Rican Parrot productivity illustrates this point. Accordingly, management techniques that promote individual nesting success can be invaluable to overall species recovery.

By using video monitoring, we were able to limit physical nest inspections only to those necessary for actual handling of nestlings or changing nest material. Reducing need for frequent nest inspections also increased safety of field personnel without concomitant reductions in nesting data or management efficacy. Eliminating unnecessary inspections also reduces molestation of nestlings and the nesting pair, which sometimes leads to nest failure in Puerto Rican Parrots (Snyder *et al.* 1987, Wilson *et al.* 1997). Furthermore, because some nest predators use olfactory cues to locate nests, reducing human visits to avian nests may also reduce nest predation in some species (Whelan *et al.* 1994, Rangen *et al.* 2000). Additionally, reduced frequency of nest inspections may also aid in maintaining a constant nest chamber microclimate. Results from captive-rearing of other Psittacines indicate that temperature fluctuations within the nest chamber can cause early embryonic mortality, the hatching of underdeveloped chicks, poor growth of hatchlings, and early hatchling mortality (Low 1986, Jordan 1989, Kuehler & Good 1990). Audiovisual monitoring provides an effective, unobtrusive method of obtaining reliable nesting data without altering nest microclimate during sensitive periods in the nesting cycle.

A major advantage of the audiovisual monitoring system is the potential to quickly detect and accurately diagnose potential problems within nests. Our prompt detection of a stealthy nest invasion by a Pearly-eyed Thrasher during the 2003 nesting season provides an illustrative example. The history of nest management for the Puerto Rican Parrot is replete with incidences of nest loss from a variety of problems (Snyder & Taapken 1977, Snyder *et al.* 1987, Lindsey 1992, USFWS 1999), many of which are difficult to detect in time to avoid nest failure. Prompt detection of potential problems provides opportunities for corrective actions, thereby improving nest success. The monitoring system also greatly reduced observer detection time for both eggs and hatchlings, thus eliminating a temporal "window" during which problem situations have often arisen undetected (Snyder & Taapken 1977, Snyder *et al.* 1987, Lindsey 1992).

Our nest monitoring technique could also be applied in the study and management of other endangered Neotropical cavity-nesters, such as the northern Pantanal population of Hyacinth Macaw (*Anodorhynchus hyacinthinus*). According to Pinho & Noguiera (2003), nest-site fidelity in this macaw population is as high as 90%, making this monitoring technique highly applicable. Similarly, audiovisual nest monitoring could be used to investigate causes of high nestling mortality of Black-billed Parrots (*Amazona agilis*) and Yellow-billed Parrots (*Amazona collaria*) in Jamaica, as reported by Koenig (2001).

Because the behavioral and nesting ecologies of many Neotropical cavity-nesters are poorly understood (Skutch 1985) and difficult to study using conventional techniques, audio-visual nest monitoring can yield unique natural history data, and provide opportunities for new and valuable ecological insights. Video monitoring of nest cavities can allow detailed studies of behavioral interactions between and among nestlings and adults, as well as unobtrusive studies of parental care and feeding (see Stoleson & Beissinger 1997). Causes of nest failures, incidences of nest parasitism, and identification of nest predators also could be determined more reliably (see Larivière 1999, Koenig 2001, Renfrew & Ribic 2003, Stake & Cimprich 2003), thus increasing knowledge of potential limiting factors and ways to ameliorate them. Further, implicit assumptions such as those regarding telemetry instrumentation or other nestling marking techniques can be tested, resulting in improved adaptive management capability. Even public educational opportunities can be enhanced with nest cavity monitoring systems, as demonstrated by the successful "QuetzalCam" which allows Internet users to observe actual nesting activities of Resplendent Quetzals (*Pharomachrus mocinno*) at Monteverde, Costa Rica (W. Lopez, CloudForestAlive.org, pers. com.).

ACKNOWLEDGMENTS

Funding for this work was provided by the U.S. Fish and Wildlife Service's Puerto Rican Parrot Recovery Program. We are grateful to all employees and volunteers of the USFWS Rio Grande Field Office who have assisted with nest monitoring, especially Wilfredo Abreu and Miguel Toledo for technical assistance with camera and microphone installations. Valeria Ojeda, Joseph Wunderle, and Chris Kellner provided helpful suggestions for improving earlier drafts of this manuscript. The mention of brand names in this study does not imply endorsement by the U.S. Department of Interior.

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