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Equipment and Techniques for Nocturnal Wildlife Studies

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Abstract

*Many biologists speculate on the nocturnal behavior of wildlife. Night-vision technologies may provide ways to move beyond speculation to observation of nocturnal activity. Nocturnal activity data collection is often secondary to broader study objectives; consequently, techniques for such studies are poorly understood and infrequently used. We reviewed 53 papers to examine image enhancement (i.e., night vision) and assess trends in nocturnal research techniques. We also conducted a field study on nocturnal behavior of roosting cranes (*Grus *spp.) to evaluate equipment function and efficacy for wildlife studies. A third-generation night-vision scope greatly outperformed a pair of first-generation night-vision binoculars, and we were able to identify cranes by species and observe and record their behaviors while they were on their nocturnal roost sites. Techniques reported in the literature included use of moonlight or natural ambient light, spotlight or simulated luminosity, remote photography, surveillance radar, infrared thermal imaging, and image enhancement. With the many techniques available, scientists can select the procedure or a combination of strategies explicit to their purpose. We believe night-viewing technologies are an exceptional, nonintrusive, functional tool for wildlife ecology studies. However, even the best equipment will have problems or issues with contrast, inclement weather, and large group size and density. Regardless of the specific method used and the inherent challenges, we believe third-generation, American-manufactured night-vision equipment can provide valuable insight into the complete life history of animals and can promote a more comprehensive approach to wildlife studies.* (WILDLIFE SOCIETY BULLETIN 34(4):1036–1044; 2006)

Key words

Grus americana, Grus canadensis pratensis, *image enhancement or intensifiers, nightscope, night-vision equipment, nocturnal activity and behavior, sandhill crane, techniques and optics, whooping crane.*

Recognition of nocturnal activities as an integral aspect of the life history of many species has increased in recent years (Robert and McNeil 1989*a*, Rompré and McNeil 1994, Hebert and McNeil 1999). Advances in technology coupled with growing interest have prompted scientists to incorporate investigations of nocturnal behaviors into research. For example, there is evidence that nocturnal foraging occurs in multiple shorebird species throughout the year and across various latitudes, including stopovers at staging areas and while wintering in coastal and estuarine habitats (McNeil and Robert 1992, Dodd 1995). Hebert and McNeil (1999) documented nocturnal floating congregations of ring-billed gulls (*Larus delawarensis*), which served anti-predator, pair-bond formation, and breeding-synchronization purposes. There are other examples of nocturnal activity in seabirds (e.g., storm petrels, shearwaters), many aquatic and wading birds (e.g., herons, ducks), and in members of 8 orders and 27 families of waterbirds, many of which are regularly or strictly nocturnal (McNeil et al. 1993).

Several fundamental hypotheses have evolved as a direct result of nocturnal ecology, such as the "supplemental," "preferential," and "predator avoidance" hypotheses (McNeil et al. 1993, McNeil et al. 1995, Dodd and Colwell 1996). Nocturnal activity also has been examined in species other than birds, such as black bear (*Ursus americanus*; Reimchen 1998*b*), Baird's tapir (*Tapirus bairdii*; Terwilliger 1978), threespine stickleback fish (*Gasterosteus aculeatus*; Mussen and Peeke 2001), and several species of deer (*Capreolus capreolus*, *Odocoileus virginianus*; Boag et al. 1990, Belant and Seamans 2000).

In addition, investigating nocturnal activities has assisted with public safety issues and has provided insight into human–wildlife interactions. For example, Belant and Seamans (2000) conducted a nighttime study to assess abundance of deer at airports and to determine the effectiveness of harassment and removal efforts to reduce nocturnal deer–aircraft collisions. In Burger and Gochfeld's (1991) study of sanderlings (*Calidris alba*), nocturnal foraging behavior was observed to determine if people had any effect on foraging success, daily and temporal foraging activities, and supplemental night feeding.

Full ecological understanding and adequate management of a species requires complete knowledge of its behavior during both day and night (Dodd and Colwell 1996). Our objectives are to 1) summarize several nocturnal techniques available for wildlife studies, 2) briefly review image enhancement and other focal-observational nocturnal techniques available for research, 3) discuss problems associated with night-vision procedures, and 4) summarize our experiences with 2 image-enhancement devices (binoculars and a pocketscope) during a study of nocturnal behavior of whooping (*Grus americana*) and sandhill cranes (*G. canadensis pratensis*) in central Florida, USA.

Study Area

We observed nocturnal behavior of cranes on 5 study sites in central Florida: a residential area (Leesburg) and a working

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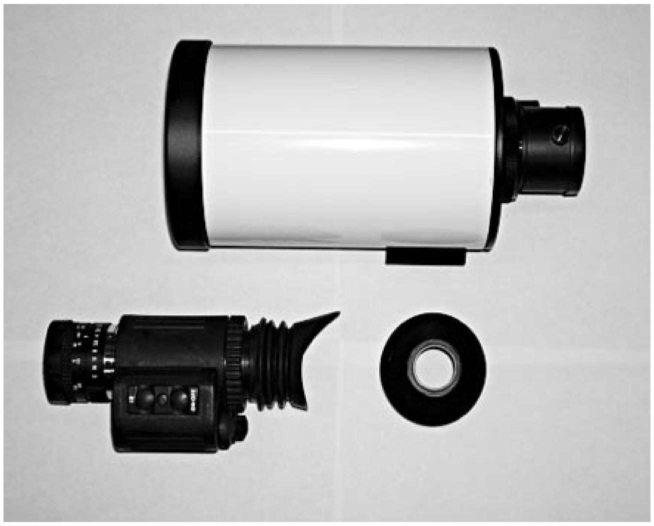

Figure 1. Field equipment for nocturnal behavior studies. American Eagle pocketscope, 500-mm C-mount lens, and lens adapter (Night Vision Equipment Company, Inc., Fogelsville, Pennsylvania).

cattle ranch (Pruitts) in Lake County, 2 lakes (East Lake Tohopekaliga [Toho] and Lake Jackson) in Osceola County, and the 5R cattle ranch in Polk County. Florida has a karst topography, largely shaped by its limestone bedrock, which supports >8,000 lakes, 1,700 rivers and creeks, and 300 springs, as well as a multitude of marshes and swamps (Alden et al. 1998). Summer months were hot (≥32°C) and humid (near 100%), while winter months were more mild (25°C). Rain was common throughout the year, with annual precipitation ranging between 123 and 131 cm (Alden et al. 1998).

Methods

Literature Review

We conducted a literature review to evaluate nocturnal techniques and to determine which practices worked best for explicit objectives. We used a series of World Wide Web search engines (e.g., Web of Science, JSTOR [a journal storage web database]). Keywords included night-vision optics, night-vision equipment, night-vision usage and techniques, infrared sensing or imaging, light–image intensifiers, image-enhancement technology, night-vision goggles or scope, nocturnal behavior or foraging, nighttime studies, nocturnal predation and predators, and crepuscular animals or predators. The literature review concentrated primarily on night-vision optics but also included studies that employed alternative methods such as spotlighting (common in deer surveys). The review was not inclusive because nocturnal activities often were secondary objectives and, thus, difficult to research. Furthermore, several techniques (i.e., spotlighting) have been used intensively in ecology and were too vast to be all-inclusive.

Night-Vision Equipment Options

We compiled a general list of night-vision techniques from our literature search, information available directly from companies and as advertised on the Internet, and based on our discussions with researchers and experts who have used night-vision equipment in the field. We gathered information on tasks for which the equipment was designed, conditions under which the equipment was subjected, differences among models, generations, and manufacturers, available options and accessories and their functions, and price.

Field Studies

We conducted a study on nocturnal crane behavior in Florida during winter–spring 2002 (Mar–May) and 2003 (Jan–Apr). We examined 2 different night-vision devices: a handheld third-generation night-vision scope equipped with a 500-mm C-mount lens (American Eagle pocketscope, Night Vision Equipment Company, Inc. [NVEC], Fogelsville, Pennsylvania [use of trade names does not imply an endorsement by the federal government]) and a pair of first-generation night-vision binoculars (Night Scout, American Technologies Network Corp., San Francisco, California; Fig. 1). The comparison between the 2 devices was warranted to test the validity of purchasing costly third-generation equipment versus more economical first-generation equipment.

The scope was either mounted on the window of the vehicle or upon a tripod. Binoculars were hand-held from the seat of the vehicle. To test distance viewing and determine the strength of the equipment, we observed cranes at various distances and angles and took notes on visibility, clarity of images, and the level of disturbance. We recorded distances the following morning, with the aid of an open-reel fiberglass tape measure, from the vehicle to the estimated center of the roost (determined by scat remains and feather plumage). We recorded weather conditions during observations, including ambient temperature, percent humidity, wind speed and direction, cloud coverage, moon phase, and time of sunset and sunrise.

We used visual observations to record nocturnal crane behaviors (Barros and Baldassarre 1989, Losito et al. 1990, Thompson and Baldassarre 1991) on sandhill cranes, juvenile whooping cranes (<2 yr), and adult whooping cranes (>2 yr). Observations ensued during all 8 phases of the moon (new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, waning crescent). We observed 1 roost locale per night and often had all 3 groups of cranes and various other species at the same roost. All whooping cranes were marked by the Florida Fish and Wildlife Conservation Commission (FFWCC) with colored leg bands used to identify birds during the day. Sandhill cranes were not marked.

We observed behaviors during 2 time periods: dusk to midnight and midnight to dawn. Observations started an hour after sunset and concluded about an hour before sunrise. Once a flock was located, we choose the first bird at random by gently shifting the night-vision equipment up and down and right to left to arrive at a random focal point within the flock. For each crane observed, we recorded species, roost site, crane number (a chronological listing of cranes observed per session), group identification (each distinct group denoted by an alphabetical letter), group composition, group size, group density, distance to nearest crane, and time started. We used time-interval sampling to record behaviors at 30-second intervals for 15 minutes (Barros and Baldassarre 1989).

Table 1. Number of papers found in ecological journals on specific nocturnal observation techniques used in wildlife studies. This compilation of literature was not exhaustive, but is a representative sample for major techniques based on key-word searches in several World Wide Web search engines (a list of key words can be found in Methods).

	Technique utilized						
Journal	**Moonlight–Natural ambient light[a]**	**Spotlight–Artifical lighting[b]**	**Remote photography[c]**	**Surveillance radar[d]**	**Infrared thermal imaging[e]**	**Image enhancement[f]**	**Multiple techniques[g]**
Acta Congressus Internationalis Ornithologici XIX						1	
Applied Animal Behaviour Science						1	
Ardea						1	
Auk	1					2	
Behaviour						1	
Biotropica		1					
Canadian Field-Naturalist						2	
Canadian Journal of Zoology	1	1	1	1			
Chesapeake Science		1					
Colonial Waterbirds						1	
Condor		1	1			2	
Current Ornithology							1
Environmental Management					1		
Herpetological Review			1				
Ibis						4	
James Ford Bell Museum of Natural History							1
Journal of Field Ornithology			1	2		1	
Journal of Mammalogy					1		
Journal of Wildlife Management	1	2		1	2	1	
Marine Ecology Progress Series		1					
Waterbirds						1	
Wildlife Society Bulletin		3	1		3	1	
Wilson Bulletin	2	1					

[a] Marshall 1942, Hailman 1964, Hunter and Morris 1976, Fetterolf 1979, Lovvorn and Kirkpatrick 1981.

[b] Progulske and Duerre 1964, Swinebroad 1964, Leck 1971, Terwilliger 1978, McCullough 1982, Fafarman and DeYoung 1986, Evans 1987, Cypher 1991, Whipple et al. 1994, McNeil et al. 1995, Dodd and Colwell 1996.

[c] Thibault and McNeil 1995, Cutler and Swann 1999, Maier and DeGraaf 2000*a*,*b*, Maier et al. 2002.

[d] Cooper et al. 1991, Burger 1997, 2001, Cooper et al. 2001.

[e] Croon et al. 1968, Graves et al. 1972, Wiggers and Beckerman 1993, Boonstra et al. 1994, Garner et al. 1995, Naugle et al. 1996, Haroldson et al. 2003.

[f] Hulscher 1976, Watmough 1978, Black and Collopy 1982, McNeil and Robert 1988, Robert and McNeil 1989*a*,*b*, Robert et al. 1989, Boag et al. 1990, Folk and Tacha 1990, Burger and Gochfeld 1991, Turpie and Hockey 1993, Rompré and McNeil 1994, Staine and Burger 1994, McNeil and Rompré 1995, Reimchen 1998*a*,*b*, Hebert and McNeil 1999, Belant and Seamans 2000, Mussen and Peeke 2001.

[g] Hill and Clayton 1985, McNeil et al. 1993.

Results

Review of Nocturnal Research Techniques

We reviewed 53 articles in 23 scientific journals that documented nocturnal or crepuscular activities or use of night-vision apparatus (Table 1). We found articles that both concentrated primarily on nocturnal activities and those that investigated nocturnal behavior as a secondary objective. We found 5 papers on use of moonlight or natural ambient light, 11 on spotlights or artificial lighting, 5 on remote cameras, 4 on radar, 7 on thermal imaging, 19 on image enhancement, and 2 that evaluated multiple techniques (Table 1).

Early studies relied on moonlight or natural ambient light and concentrated on colonial-nesting birds (Marshall 1942, Hailman 1964, Hunter and Morris 1976, Fetterolf 1979). Studies were restricted to moonlit nights and occasionally employed disruptive tactics such as flushing (Marshall 1942). These techniques often led investigators to anecdotal observations and unsubstantiated conclusions. For instance, Marshall (1942) studied the causes of night desertion in nesting common terns (*Sterna hirundo*) and documented black-crowned night herons (*Nycticorax nycticorax*) consuming tern eggs but failed to provide data on numbers of eggs taken, numbers of terns flushed by the predator, or numbers of terns remaining. Furthermore, studies that depended on moonlit nights did not account for increased activity during full-moon phases and were forced to speculate on obscure activities.

Other early methods included use of flashlights and headlamps (Swinebroad 1964, Terwilliger 1978) or spotlights and frontal lighting (equipped with or without red filters; Progulske and Duerre 1964, McNeil et al. 1995, Dodd and Colwell 1996, Belant and Seamans 2000). Spotlighting, a technique often used in the estimation of deer abundance, offers low costs, simplicity in use, nominal disturbance, and comparability of relevant data (Belant and Seamans 2000). Problems with spotlighting include decreased effectiveness under adverse weather conditions and concealing vegetation, intrusiveness for both animals and humans, and detection difficulties dependent upon reflection (McCullough 1982, Cypher 1991, Belant and Seamans 2000). Whipple et al. (1994) found that estimating deer density and age and sex ratios with spotlighting techniques proved inadequate and recommended replication of counts along survey routes to increase precision (McCullough 1982, Fafarman and DeYoung 1986). Furthermore, spotlight counts tend to overestimate deer density in open canopies and underestimate density in closed canopies (McCullough 1982, Whipple et al. 1994). Red filters eliminate unfiltered light disturbance, yet spotlights still perform poorly under inclement weather (McNeil et al. 1995, Dodd and Colwell 1996).

Remote photography (time lapse and triggered camera or video systems) has become increasingly popular as a method for addressing wildlife issues, such as avian feeding ecology, identifying nest and egg predators, and documenting behaviors such as incubation (Thibault and McNeil 1995, Cutler and Swann 1999), that are difficult to accomplish with traditional methods. Despite its advantages, remote photography suffers from technical problems, requires frequent monitoring, and is often conspicuous to animals and humans (Cutler and Swann 1999). Maier and DeGraaf (2000*b*) attributed an estimated 70% of the unidentified predation events in their study of avian-nest predators to equipment failure. Other potential problems arise from possible confounding effects, such as attracting nontarget animals and humans to camera sites and camera acclimation, particularly when bait is used (Cutler and Swann 1999, Maier et al. 2002). Although remote photography can provide detailed information on a variety of subjects, researchers are urged to understand the limitations of such data. For example, while unambiguous evidence exists (photograph), multiple photographs of a species is not an estimator of abundance (e.g., estimating population parameters), nor does it necessarily identify the initial predation event (e.g., nest predation; Cutler and Swann 1999, Maier and DeGraaf 2000*b*).

Thermal imaging is fast becoming a preferred technique to estimate mammal population sizes for management objectives, such as setting harvest quotas and verifying population trends. Problems include an inability to detect animals of contrasting sizes in varying habitats, observer and sampling technique bias, inclement weather and concealing vegetation, and costs (Croon et al. 1968, Garner et al. 1995, Naugle et al. 1996). Despite drawbacks, thermal imaging and infrared linescanning have been effective in the census of small mammals (Boonstra et al. 1994) and determining population demographics (e.g., sex ratios) of deer (Wiggers and Beckerman 1993). Thermal imaging offers several advantages over traditional censusing techniques, including detection at greater distances, minimizing cryptic-coloration distortion problems, and eliminating intrusive methods (Haroldson et al. 2003). However, experts warn that until additional research is collected on the ability of infrared to distinguish between correct and incorrect objects, and advances are made in hardware and software development (e.g., concerning the calculation of ground coverage in real time), thermal imaging remains problematic (Garner et al. 1995, Haroldson et al. 2003).

Marine radar devices are fast becoming a useful tool for ornithological research in detecting and estimating abundance of birds throughout the night, at crepuscular times, and during inclement weather (Cooper et al. 1991). Specifically, marine radar has been fundamental in estimating populations of marbled murrelets (*Brachyramphus marmoratus*; Burger 2001). Counts provide valuable information on macrohabitat preferences, comparison of watersheds for land-use management, and tracking long-term changes in populations (Burger 2001). Shortcomings include scanning area restrictions, inability to detect birds flying below or within the forest canopy, limited information on flock size, altitude, and flight behavior, nominal information on vocalizations, and decreased effectiveness under adverse weather (Burger 1997, Cooper et al. 2001). Nonetheless, radar has potential as a cost-effective, nonintrusive tool and is useful as an index of population estimates and trends (Cooper et al. 2001).

Image-Enhancement Technologies

There are 2 distinct technologies in which night vision operates: image enhancement or intensifiers (light amplification) and thermal imaging (infrared). Image intensifiers collect light from the lower portion of the infrared light spectrum and then amplify and convert photons into electrical energy (Tyson 1998). Thermal imaging gathers the upper segments of the infrared light spectrum and emits that light as heat (Tyson 1998).

The United States and Russia manufacture most night-vision equipment, which is divided into 4 broad categories: scopes (monocular), goggles (binocular), cameras, and weapon sights. Scopes, primarily designed for surveillance applications, can be hand-held or tripod-mounted and generally are small, lightweight, and versatile (NVEC 2001). Goggles (available in dual- and single-tube models) can be head-mounted or hand-held, offer depth perception, and work best for movement and range detection needs (NVEC 2001). Night-vision cameras (predominantly used for surveillance purposes) require a permanent location and work well for activities that require extended durations (Tyson 1998).

Generation indicates the level of technology and, therefore, the degree of sophistication of the equipment (Fig. 2). Generations include zero, first, second, and third, with a chronological level of technology. Zero-generation equipment, developed in the 1940s and 1950s, requires active infrared (a projected source of infrared illumination), has a photosensitivity of 60 microamps of current per lumen of light (mA/lm; Table 2), a short tube-life operation, and problems with image distortion (Tyson 1998, NVEC 2001). First-generation devices, developed in the 1960s, use passive infrared ambient light (no source of projected infrared light required), have a photosensitivity of 180–200 mA/lm, a tube operating life of 100–2,000 hours, require full moon operation, and are characterized as having image distortion (Tyson 1998, Morovision 2000, NVEC 2001). Second-generation tools, developed in the 1970s, require one image tube (Table 2; compared with the 3 obligatory tubes in first-generation systems), have a photosensitivity of 240+ mA/lm, a tube operating life of 2,500–4,000 hours, one-quarter moon operation capabilities, and low image distortion

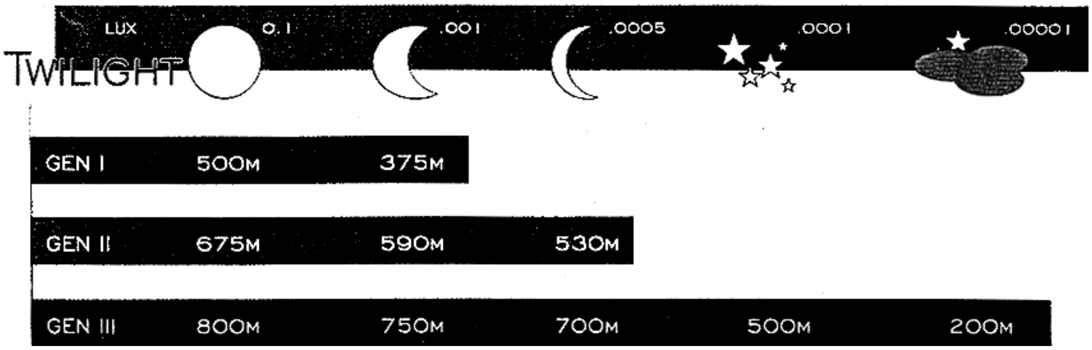

Figure 2. Degree of night illumination necessary is a function of the technology employed. Minimum operating light levels for each generation are depicted. The distance in meters (m) is the range at which a 6-foot-tall man can be seen. Night Vision Equipment Company, Inc., used by permission.

(Tyson 1998, Morovision 2000, NVEC 2001). Third-generation equipment, developed in the late 1970s and early 1980s, has improved distance viewing, resolution, and sensitivity capabilities, photosensitivity of 800+ mA/lm, a tube operating life of >10,000 hours, and starlight operation (Tyson 1998, Morovision 2000, NVEC 2001).

Performance level is determined by 4 attributes: photosensitivity, signal-to-noise ratio (SNR), luminance gain, and image-intensifier resolution (Table 2; Morovision 2000, NVEC 2001). Typically, when referring to the image tube of a night-vision tool, manufacturers will give specific details about photosensitivity (a.k.a. photocathode response), which distinguishes among generations (NVEC 2001). Photosensitivity is the capability of the image tube to detect and convert available light; a higher numerical value will produce visible images under faint light conditions (Morovision 2000, NVEC 2001). Signal-to-noise ratio, which is the computed ratio of measured data from photosensitivity, gain, and resolution, is the single best indicator of an image intensifier's performance (Morovision 2000, NVEC 2001). High SNRs will display clear images with good contrast under low light conditions (Morovision 2000, NVEC 2001). Luminance gain is the intensifier tube's ability to amplify detectable light input; higher gains provide the best images (NVEC 2001). Resolution is the ability to resolve detail (i.e., distinguish among crowded objects) in an image and is an important indicator of the quality of the system (NVEC 2001). Higher resolution results in more defined clarity among objects.

Generally, most of the equipment advertised and recommended on the Internet was modestly priced (<$500) second- or third-generation, recreational, Russian-manufactured equipment. Price for first-rate, third-generation night-vision equipment can range into tens of thousands of dollars. However, it is possible to obtain premium second- or third-generation equipment at a price range of $1,000–8,000.

Crane Observations

The night-vision binoculars portrayed an unclear, opaque, blotchy image, which often became increasingly worse under low light conditions. Therefore, all behavior observations

Table 2. Common night-vision terminology (Morovision 2000, Night Vision Equipment Company, Inc. 2001).

Terminology	Definition
Luminance gain (brightness gain)	The number of times a night-vision device amplifies light input. It is usually measured as tube gain and system gain and is estimated in values of tens of thousands.
Line pairs	An expression of resolving power. The more line pairs defined per unit length will produce better resolution. Expressed in line pairs per millimeter.
Photosensitivity (photocathode response)	The ability of the photocathode to produce an electrical response when subjected to light waves (photons). Measured in microamps of current per lumen of light.
Image-intensifier resolution	The constant ability of an image-intensifier or night-vision system to distinguish between objects close together. Measured in line pairs per millimeter.
Signal-to-noise ratio (SNR)	The low-light resolution of a image tube. The higher the SNR, the better the ability of the tube to display objects with good contrast under low-light conditions.
Cosmetic quality (tube blemishes)	Common cosmetic blemishes in image-intensifier tubes that are inherent in manufacturing. Blemishes have no effect on operation or reliability of device.
Diopter	Unit of measure that defines eye correction to the refractive power of a lens. Most night-vision systems provide a range of +2 to −6.
Eye relief	The distance that eyes must be from the last element of an eyepiece in order to achieve the optimal image area.
Automatic brightness control	An electronic feature that automatically reduces voltage to the microchannel plate to keep the image-intensifier's brightness within optimal limits and protects the tube.
Bright source protection (BSP)	An electronic function that reduces the voltage to the photocathode when the night-vision device is exposed to bright light sources such as room or car lights. The BSP protects the image tube from damage and enhances its life, but also lowers resolution while functioning.
Image-intensifier tube	Tube in light-amplification devices that collects and amplifies infrared and visible light. Each tube has a photocathode, which converts photons of light energy into electrons.

Figure 3. Using night-vision equipment, we could easily distinguish between species and among individuals of whooping cranes and sandhill cranes in central Florida, USA. To the left, 2 roosting whooping cranes perpendicular to each other; to the right, 2 roosting sandhill cranes standing next to each other. Note that image quality diminishes with the addition of equipment (i.e., pocketscope, lens, and video camera).

were collected with the night-vision scope only. We could not identify whooping cranes by colored leg bands or differentiate among age classes, but we could distinguish among species (Fig. 3). During the first field season (2002), we collected 120 sandhill crane and 67 adult whooping crane observations, but were not allowed access to juvenile whooping cranes because of disease concerns, which may have resulted in the death of 11 of 19 released birds. During the second field season (2003), we collected 124 sandhill crane, 94 adult whooping crane, and 83 juvenile whooping crane observations.

We observed cranes at varying distances (96–500 m). Observations proved most efficient when cranes were positioned ≤300 m from the observer. Dim backgrounds, such as suburban structures or dense, tall vegetation, cast shadows and decreased visibility. Cloud cover, humidity, temperature, precipitation, and moon phase affected visibility, but wind had no effect. Cloud coverage of 65–80% had no effect on observations when the moon was in its first-quarter, waxing gibbous, full, waning gibbous, or last-quarter phases. Cloud coverage of 65–80% did affect observations during new and crescent moon phases because of deficient ambient light. Coverage of 80% or more was insufficient for observations during all moon phases. Highly humid (80–90%) and foggy weather blurred the image and frequently clouded the scope lens, which occasionally prohibited observations. Temperatures below 3.3°C produced lens condensation, which produced inferior observations. Precipitation prohibited observations as the scope was not water resistant. New, waxing crescent, and waning crescent moon phases produced substandard observations. First quarter, waxing gibbous, full, waning gibbous, and last quarter were all profitable moon phases for observing. The best phase for observations was the full moon.

We observed multiple groups of varying sizes (1–82 individuals). With increasing group size and density (i.e., cranes packed tightly together), individuals blended together, which made observations difficult (Fig. 4). Furthermore, in larger masses, cranes often rearranged their position within the flock, which disrupted observations. We experienced no difficulty in distinguishing among species (i.e., sandhill crane, whooping crane, wood storks [*Mycteria americana*]). In addition, we identified several other species at crane roost sites, such as black-crowned night-herons, raccoons (*Procyon lotor*), northern river otters (*Lontra canadensis*), alligators (*Alligator mississippiensis*), feral pigs, striped skunks (*Mephitis mephitis*), white-tailed deer (*Odocoileus virginianus*), gray fox (*Urocyon cinereoargenteus*), and feral dogs (*Canis familiaris*).

Figure 4. (a) Nine whooping cranes at Pruitts Ranch, Lake County, Florida, USA. Multiple roosting cranes in close proximity can cause blending problems and inhibit distinction. (b) Sandhill cranes experience the same blending problems (12 sandhill cranes and 2 whooping cranes at the 5R Ranch, Polk County, Florida).

Discussion

Field Equipment and Techniques

The first-generation night-vision binoculars were not an effective tool for the observation of cranes. Problems included difficulties in tracking a mobile bird for the full 15-minute observation period and distinguishing among individuals, between age classes, and among species at a distance of ≥100 m. In addition, the binoculars performed poorly under placid weather conditions and were awkward, bulky, and heavy relative to their size. Early inferior technologies often

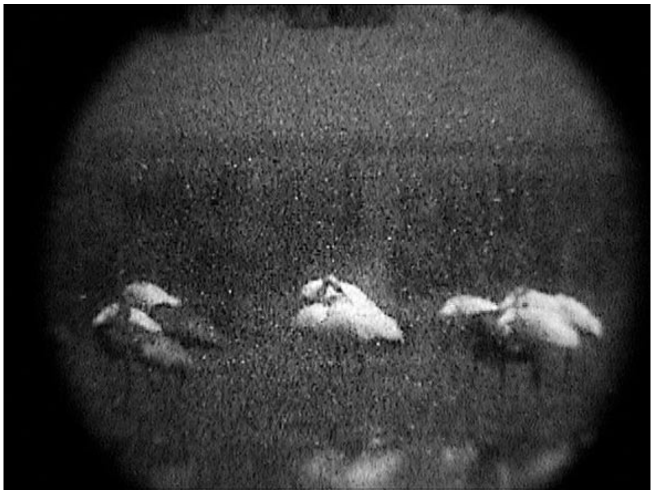

Figure 5. Specific detail is possible with the appropriate night-vision equipment. Here we witness a whooping crane preening and can clearly see its red bare skin patch (portrayed as black through scope), located on the crown.

included multiple image tubes within one system, making zero- and first-generation equipment larger and heavier compared to modern technologies, which utilize one image tube (Morovision 2000). Although we did not find these specific binoculars functional for our study, highly developed goggles are versatile and optimal for motion-based studies. In particular, studies focusing on tracking or behavior would find the flexibility of goggles advantageous.

Observations with the third-generation night-vision scope were clear, consistent, specific, and reliable. The scope was weather-durable, constructed for detailed distance viewing (with the addition of a 500-mm C-mount lens), suitable to the purpose of our behavioral study, lightweight, and uncomplicated in use. We observed mobile and still birds from the stationary field vehicle for the complete observation period (15 min) and could easily discriminate among species within a distance of 500 m. Night-vision scopes work best for stationary studies and are suited for long-duration, detailed viewing. Most pocketscopes are equipped with minimal magnification (powers 1–3); therefore, studies requiring detailed observations should use image intensifiers that are threaded to accommodate additional camera accessories (i.e., in-line attachment magnification lenses) for direct viewing. Those studies involving distance viewing and, therefore, increased magnification should provide a stable environment to mount the scope, as increased power usually requires minimal movement for clarity.

Problems Associated With Nocturnal Crane Observations

Clear, visible observations and behavior distinction were limited to a maximum distance of 300 m. Studies involving smaller animals (cranes stand at 132 cm and weigh 5–6 kg) might benefit from more advanced equipment or a lens with greater magnification. Background difficulties were site specific and dependent upon the surrounding composition (i.e., emergent vegetation, light pollution, water basins). Suburban roosting sites suffered excessive volumes of light pollution and, therefore, constricted viewing angles, as was the case with the Toho site, which was close to Orlando International Airport, a baseball stadium, and local highways. We do not recommend image intensifiers for urban studies. Researchers conducting urban studies can expect inferior viewing conditions and viewing restrictions and run the risk of damaging the equipment. Most night-vision equipment manufacturers recommend against directing night-vision devices at artificial light sources, which may harm the image tube. Covert infrared spotlights and filters (for use with standard flashlights) increase detection range and enhance image quality of any night-vision apparatus, and would mitigate light pollution and background problems, as well as difficulties with moonless nights and adverse weather (NVEC 2001). In addition, for studies focusing on crepuscular activities, there are products specifically fashioned for twilight viewing and, therefore, more functional than standard night-vision equipment.

The distinctive white plumage of whooping cranes was easy to see at night. However, the more camouflaged sandhill crane has mottled brown and gray plumage and at times (e.g., overcast sky) was difficult to view against emergent vegetation. Studies of cryptic animals would benefit if reflective tape could be used to help distinguish individuals from one another and from their environment. Hill and Clayton (1985) list a variety of nocturnal marking techniques useful to behavioral studies. Although we could not view FFWCC bands clearly, we could identify other significant markings, such as the bare skin patch on the crown of both species of cranes, which would indicate that marking techniques could be a valuable procedure (Fig. 5).

Group size and relative proximity of surrounding cranes added to image confusion. In larger assemblages (i.e., >20 birds), it was common to lose the focal bird during mass interchanges. In instances where we were unable to identify the focal bird, we discontinued observations and moved on to the next random bird. Blending and confusion problems associated with larger groups of cranes can be minimized by observing smaller assemblages. However, even with small groups, periods of unknown behaviors will be likely. We suggest employing nocturnal marking methods to increase animal contrast, distinguish among individuals, and thereby increase the potential of the viewing instrument (Hill and Clayton 1985).

Image-Enhancement Equipment

Selecting equipment.—There is a wide spectrum of quality, performance, physical features, cost, and ease of operation available for night-vision equipment. Study objectives and location (i.e., environment and climate) should dictate technique. Other considerations involve physical features of the equipment, such as size, weight, and ease of operation, as well as durability and weather resistance, field of view, duration of study, and price.

One characteristic common throughout all night-vision devices, regardless of level of technology, is tube blemishes (a.k.a. black spots). Black spots are cosmetic blemishes in the image-intensifier tube. They do not affect performance or reliability; they are, however, a mark of production quality, and fewer blemishes generally are the result of quality products (NVEC 2001). We found the spots had no effect on our study or visibility.

The image tube is the single most important element of any night-vision tool and represents 75% of the overall system cost (Morovision 2000). Image-tube statistics are the biggest indicator of performance. Researchers planning long-term studies should carefully consider tube operating life and contemplate buying more advanced systems to minimize problems related to repair costs and tube replacement. Within our intensive 2-year study span, we had no need for tube replacement and required minimal repairs, totaling $125.00, which included cleaning of the unit, retesting and replacement of the battery cap and mounting screws, and shipping.

Generation, manufacturer, and price.—Sophistication, manufacturer, and price dictate quality. Early technologies, zero- and first-generations, relied on projected infrared light (usually attached to the device) and generally were considered poor grade. Most first-generation systems are Russian-made, inexpensive, and oriented toward the novice; zero-generation equipment is essentially obsolete and no longer made by United States manufacturers. Night Vision Equipment Company, Inc. (NVEC 2001), a United States night-vision equipment manufacturer, states that while Russian-produced equipment uses the same generation classification as the United States (first, second, and third generations), by world standards Russian equipment is inferior to United States products and should be listed as zero, first, and second generations, respectively. Although we purchased our binoculars through an American-based company, the manufacturer was Russian. This is typical in the night-vision industry and we urge consumers to inquire about manufacturer before purchase. Zero and first generations are basic-level technologies; they experience problems with image distortion, work poorly under overcast and moonless nights, and have a reduced tube lifespan (Tyson 1998). Second and third generations are the most advanced systems and provide a substantial improvement in image, ease of use, and tube life over early generations (Morovision 2000).

Nocturnal research is an unpredictable and still somewhat unfamiliar discipline. However, it is also integral to a full understanding of the ecology of virtually all wildlife. We have presented a number of modern strategies for conducing nocturnal studies. Success depends upon a strong goal, well-defined objectives, and equipment comprehension. Each technique has pros and cons that make it well suited or ill equipped for specific study purposes. Several fundamental points to consider before choosing a technique include the goal of the study, requirements of the study (e.g., level of movement, detail, and distance), and the environment (e.g., weather, climate, surroundings, etc.). These points will dictate methodology.

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