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**TERYL G. GRUBB,**[1] *United States Forest Service, Rocky Mountain Research Station, 2500 S Pine Knoll Drive, Flagstaff, AZ 86001, USA*

**DAVID K. DELANEY,** *United States Army Engineer Research and Development Center, Construction Engineering Research Laboratory, 2902 Newmark Drive, Champaign, IL 61822, USA*

**WILLIAM W. BOWERMAN,** *Department of Forestry & Natural Resources, 261 Lehotsky Hall, Clemson University, Clemson, SC 29634, USA*

**MICHAEL R. WIERDA,** *Department of Forestry & Natural Resources, 261 Lehotsky Hall, Clemson University, Clemson, SC 29634, USA*

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**TERYL G. GRUBB,**[1] *United States Forest Service, Rocky Mountain Research Station, 2500 S Pine Knoll Drive, Flagstaff, AZ 86001, USA*

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**MICHAEL R. WIERDA,** *Department of Forestry & Natural Resources, 261 Lehotsky Hall, Clemson University, Clemson, SC 29634, USA*

**ABSTRACT** In 2006–2007, during Wasatch Powderbird Guides (WPG) permit renewal for heli-skiing in the Tri-Canyon Area (TCA) of the Wasatch Mountains, Utah, USA, we recorded 303 helicopter passes between 0 m and 3,000 m (horizontal distance) near ≥30 individual golden eagles (*Aquila chrysaetos*) in 22 nesting territories, through passive observation and active experimentation with civilian and military (Apache AH-64) helicopters. Flight profiles included 800-m, 400-m, 200-m, and 100-m flybys (horizontal distance from cliff nest on parallel course), as well as approaches and popouts where helicopters flew toward, or popped out from behind, adult-occupied cliff nests (0 m, horizontal distance). Between 1981 and 2007, during the only 8 years when nesting in the TCA was confirmed by presence of chicks, WPG annually flew 108–2,836 helicopter flights in the same drainages on 10–37 days between 15 December and 15 April, with no effect on early courtship, nest repair, or subsequent nesting success. Total WPG operating days ($\bar{x} = 62.4$) and helicopter hours ($\bar{x} = 210.6$) fluctuated annually but did not increase 1974–2007 (Cox–Stuart trend test, $P = 0.371$, 0.393, respectively). Apache helicopter testing (227 passes) did not reduce golden eagle nesting success or productivity rates within the same year ($t_{111,\,96} = 0.495$, 0.782, $P = 0.622$, 0.436, respectively), or rates of renewed nesting activity the following year, compared with 81–101 non-manipulated nesting territories. We recorded no response during 66% and only watching during 30% of Apache passes at 0–800 m from nesting golden eagles. No other reactions occurred until after hatching when ≤4 golden eagles accounted for 5 flatten and 3 fly behaviors at 3 nest sites. No responding pairs failed to fledge young because of testing. Limited fly responses suggested helicopters only precipitated an imminent departure, rather than causing startled, avoidance reactions. Responsiveness between test weeks 1 and 2 decreased ($\chi^2_2 = 32.167$, $P \leq 0.001$). Apache helicopters were twice as loud as WPG helicopters at comparable distances. Sound decreased with distance, most rapidly when flights were perpendicular to cliffs or ridges. Eagle ambient behaviors and watching the helicopter occurred randomly throughout recorded sound levels during helicopter testing (76.7–108.8 decibels, unweighted). Much helicopter sound energy is below golden eagles' auditory threshold, thus reducing potential impacts. Neither our observations nor our testing indicated special management restrictions are required for helicopters flying near nesting golden eagles in northern Utah. Our results underscore the necessity for circumstance-specific research, as well as enlightened resource management to accommodate unexpected results.

**KEY WORDS** aircraft, buffers, golden eagle, helicopter, heli-skiing, human disturbance, management, military, noise, recreation.

Assessing effects of human disturbance on raptors, or wildlife in general, is a complex, multivariate problem with variable results depending on circumstances and characteristics of both the anthropogenic activity and responding target species. Golden eagles (*Aquila chrysaetos*) and red-tailed hawks (*Buteo jamaicensis*) exposed to human intrusions during early incubation had significantly lower reproductive rates than individuals exposed later in the season (Steenhof and Kochert 1982). However, Kochert et al. (2002) recorded no adverse effects from 906 helicopter flights near active (Appendix) golden eagle nests during aerial surveys to check on eggs and nestlings. Yet, golden eagles also have attacked small fixed-wing aircraft and helicopters, most commonly when aircraft approached a sexually displaying pair of eagles at the same or slightly lower level (Bruderer 1978). Platt (1977) reported gyrfalcons (*Falco rusticolus*) relocated to nearby nests after a year of close disturbance by helicopters. In the year after a jet overflight study, 5 osprey (*Pandion haliaeetus*) pairs continued nesting with no changes in location (Trimper et al. 1998). These ospreys showed no startle or flush reactions to low-level jet overflights between 0 km and 1.4 km but did react with agitation, flight, and aggressive behavior to helicopters, float planes, and humans. After extensive controlled experimentation with military jet helicopters over Mexican spotted owls (*Strix occidentalis*), manipulated and non-manipulated sites did not differ in reproductive success or number of young fledged (Delaney et al. 1999).

Although various forms of human disturbance can negatively impact birds of prey (Mathisen 1968, Fyfe and Olendorff 1976, Fraser et al. 1985, Richardson and Miller 1997), research targeting potential aircraft impacts on raptors is limited (Awbrey and Bowles 1990, Ellis and Ellis 1991, Grubb and Bowerman 1997, Trimper et al. 1998). Even fewer studies have specifically addressed effects of any kind of anthropogenic activity on golden eagles (Boeker 1970, Ellis 1975, Anderson et al. 1990, Holmes et al. 1993, Steidl et al. 1993). Research results vary depending on an array of factors including but not limited to type, severity, timing, duration, frequency, and proximity of the stimulus, as well as activity, location, and buffering (vegetational or physiographic) associated with the target species (Grubb and King 1991). Individual behavioral tendencies and previous experience or exposure also can affect the type,

[1] *E-mail: tgrubb@fs.fed.us*

severity, and duration of response. Local population of the target species and any habituation to existing levels of human activity in the potential conflict area also should be considered. The National Bald Eagle Management Guidelines (U.S. Fish and Wildlife Service 2007), which also include golden eagles, recommend a 305-m buffer for helicopters around bald eagle (*Haliaeetus leucophalus*) nests during the nesting season, except where eagles have demonstrated tolerance for such activity (page 14).

Since 1973, Wasatch Powderbird Guides (WPG) has operated a helicopter skiing service under a United States Forest Service (USFS) Special Use Permit. The 2004 Final Environmental Impact Statement: WPG Permit Renewal (FEIS; USFS 2004*a*) mandated 800-m buffers around occupied golden eagle nests between 1 February and 31 August and restricted helicopter flights <305 m above ground level (AGL) or <48 km/hr when buffers were in effect. Responsibility under the Bald and Golden Eagle Protection Act (1940, as amended in 1962) is to ensure that USFS activities and those that it authorizes do not result in an act-defined take of golden eagles. Based on available information, legal requirements, and documented concerns, the FEIS concluded that, with the recommended management actions, WPG's operations under the USFS permit would have little or no long-term effect on golden eagles nesting in the Tri-Canyon Area (TCA) of the Wasatch Mountains, Utah, USA. However, in its 2004 Record of Decision for WPG Special Use Permit Renewal the USFS (2004*b*) encouraged a comprehensive study to more intensively examine helicopter–golden eagle interactions.

The goal of this proposed investigation was to gather more specific information on the potential impacts of heli-skiing helicopters on golden eagles nesting in the TCA while evaluating effectiveness of management practices identified in the FEIS. Given the variability in raptor response to helicopters and subsequent range of potential management alternatives, as well as the absence of specific data on either heli-skiing or experimentally derived helicopter effects on golden eagles, our objectives included 1) analysis of historical records for golden eagle nesting in the TCA along with WPG operational records for any evidence of disturbance or tolerance, 2) direct observation of heli-skiing helicopter effects on nesting and behavior of golden eagles in the TCA, and 3) experimental testing for current buffer and response-threshold distances with controlled helicopter flights near nesting golden eagles in the TCA and surrounding area.

## STUDY AREA

Our primary study area was the TCA, which included Little and Big Cottonwood canyons and Mill Creek Canyon, located on the Wasatch-Cache National Forest (WCNF) in the central Wasatch Mountains immediately east of Salt Lake City (40°45′N, 111°54′W) in Salt Lake, Wasatch, and Utah counties, Utah. We surveyed and monitored golden eagle nesting from Parley's Canyon, approximately 5 km north of the TCA, to Provo Canyon, approximately 30 km south. For helicopter testing, we expanded the study area to include active nesting territories in Tooele and Box Elder counties, southwest of Salt Lake City and west of the Great Salt Lake, respectively.

Centrally located within the heart of this study area lie the Salt Lake Valley and Wasatch Front, with a rapidly growing population of >1.7 million people (Salt Lake Travel and Visitor Center 2007). The Wasatch Front is approximately 130 km long extending from Ogden, approximately 65 km north of the Salt Lake Valley, to Provo, the same distance south. The Wasatch Front lies immediately adjacent to the TCA and encompasses canyons running east into the mountains along the entire front range. The Salt Lake City–Ogden area alone grew from 910,222 people in 1980 to 1,333,914 people in 2000, an increase of >46% (U.S. Census Bureau 2000). More than 1.5 million skiers per year visited the 4 major resorts in the Cottonwood canyons (Alta Ski Area, Brighton Resort, Snowbird Ski and Summer Resort, and Solitude Mountain Resort; WCNF staff, unpublished data). Nearly 10,000 vehicles per day entered the same 2 canyons, where >15,000 explosions per year were detonated for avalanche control (Utah Department of Transportation, Region 2, Avalanche Safety and Traffic Operations staff, unpublished data). Eight other civilian organizations, in addition to WPG, flew ≥17 helicopters in and around the TCA during our study.

Along the Wasatch Front between Parley's and Provo canyons, there were ≥20 golden eagle nesting territories (K. Keller, Utah Department of Corrections, unpublished data), of which 15 were occupied and 4 were confirmed active in 2006 (see Appendix for terminology). Nest locations, historical information, and traditional territory characteristics throughout the golden eagle's range suggest ≤5 nesting pairs in the TCA (WCNF staff, unpublished data). Golden eagle egg-laying in northern Utah begins in late February to early March at lower elevation sites (≤1,524 m), mid- to late March at mid-elevation sites (1,524–2,134 m), late March to mid-April at high elevation sites (2,134–2,743 m), and probably not until May at any higher elevation sites (K. Keller, personal communication). Tri-Canyon Area nesting territories fell within the latter 2 elevational ranges. However, fewer golden eagles nest at higher (>2,743-m) elevations, which are on the periphery of their local nesting range, they do so less frequently than at lower elevations, and they are less successful in fledging young (Keller 2006, 2007).

## METHODS

We compiled historical records of golden eagle presence and nesting activity for 1981–2003 from WCNF files. Data sources included USFS and civilian observers and were supplemented with sightings from WPG records. K. Keller (unpublished data) provided historical nesting data for several additional sites in the TCA. From WPG records since they began operations in winter 1973–1974 through the second year of our study, 2007, we calculated annual totals, long-term trends, and overall means for operating days and helicopter flight hours per year. We also determined the frequency of individual WPG helicopter

**Table 1.** Comparative specifications and sound levels for 4 helicopter models used to fly near nesting golden eagles in northern Utah, USA, 2006–2007.

| Specification | AH-64 Apache[a] | Eurocopter AS350 B3[b] | Eurocopter EC130-B4[c] | Bell 206 L4[b] |
|---|---|---|---|---|
| Rotor length (m) | 14.6 | 10.7 | 10.7 | 11.3 |
| Fuselage length (m) | 15.1 | 10.9 | 10.7 | 11.1 |
| Overall length with both rotors (m) | 17.7 | 12.9 | 12.6 | 12.9 |
| Empty wt (kg) | 5,165 | 1,228 | 1,369 | 1,056 |
| Powerplant | Twin turboshaft | Single turbine | Single turbine | Single turboshaft |
| Overhead noise levels[d,e] | | | | |
| Unweighted SEL (dB) | 106.5–110.0 | 98.0–99.9 | 97.4–97.8 | 100.4–100.9 |
| (A weighted, dB) | (94.7–99.3) | (85.7–89.0) | (83.0–84.2) | (86.5–91.1) |
| No. and type passes | 5 field | 4 simulated | 4 simulated | 2 simulated |
| 100-m noise levels[e,f] | | | | |
| Unweighted SEL (dB) | 102.3–109.0 | 97.0–97.3 | 96.6–97.0 | 100.0 |
| (A weighted, dB) | (88.2–97.1) | (84.8–85.2) | (82.0–82.3) | (84.5–89.0) |
| No. and type passes | 25 field | 4 simulated | 4 simulated | 2 simulated |

[a] Boeing Defense, Space & Security (Berkeley, MO); operated by Utah National Guard, 211th Aviation Attack Helicopter Unit (West Jordan, UT).
[b] Eurocopter: Division of European Aeronautic, Defense and Space Company (Marignane, France) and Bell Helicopter Textron, Inc. (Fort Worth, TX), operated by Wasatch Powderbird Guides (Snowbird, UT).
[c] Operated by Cirque Lodge (Sundance, UT).
[d] Unweighted and A weighted sound exposure levels (SEL, decibels [dB]) for 3 civilian helicopters flown at 92 m above ground level at 111 km/hr, directly overhead of sound recording equipment under simulated test conditions, and similar flight patterns flown by AH-64 Apache helicopters during field trials near nesting golden eagles.
[e] Average 10-sec equivalent energy levels for ambient sound were 44–48 dB, A weighted.
[f] Unweighted and A weighted SEL (dB) for 3 civilian helicopters flown at 92 m above ground level at 111 km/hr, 100 m from sound recording equipment under simulated test conditions, and similar flight patterns flown by AH-64 Apache helicopters during field trials near nesting golden eagles.

flights within the same TCA drainage where golden eagle nesting was confirmed by presence of chicks for 6 years from historic records and 2 years of our study.

Experimental site selection and population productivity comparisons were made possible by long-term monitoring of >200 golden eagle nesting territories in northern Utah (Keller 2006, 2007). Keller monitored all test sites before and after our experimentation with helicopters. In addition to the initial guided visit and actual days of testing, we revisited all test sites 2–4 times to plan observation points, microphone positions, and helicopter flight paths. To monitor golden eagle behavior patterns before and after each helicopter pass during testing, observers with spotting scopes located themselves approximately 400–1,200 m from each nest, viewed from either a parked vehicle (on a road within the nesting territory where occasional vehicular traffic was common) or from behind camouflaging natural vegetation and terrain features. Neither technique affected golden eagle behavior at these distances. Observers recorded golden eagle ambient activities for ≥1 hour before the first scheduled helicopter test, monitored activity and any responses during and between tests, and continued to record eagle activity for ≥1 hour after the helicopter's final departure from the test site. We recorded all golden eagle movements, changes in orientation, and behaviors during these continuous observations, which usually lasted between 3 hours and 4 hours. Our experimental approach used manipulated eagles as their own controls for measuring frequency, type, and severity of behaviors before, during, and after experimentation. We orally recorded most field notes in real time on digital tape recorders (DATs) with internal clocks synchronized among all test sites and sound recording units.

We studied 4 types of aircraft (Table 1) during 2006–2007, when WPG primarily operated 2 Eurocopter AS350-B3s (AStars; Eurocopter: Division of European Aeronautic, Defense and Space Company, Marignane, France), and only used a Bell 206 L4 (Bell Helicopter Textron, Inc., Fort Worth, TX) late in the 2006 heli-skiing season. We actively recorded golden eagle responses to helicopters during controlled experimental flights (as detailed below) and additional survey flights when one of the authors was in the survey helicopter; and we passively, or opportunistically, recorded responses as other circumstances permitted. Examples of the latter group include extra passes by AH-64 Apaches (Boeing Defense, Space & Security, Berkeley, MO), usually in transit between test sites; observations of WPG flying in drainages where we were independently observing eagles; and the occasional civilian helicopter flying near nests being monitored for Apache trials.

We designed Apache test flights to simulate as closely as was practical the timing and duration of typical WPG back country heli-skiing operations, with 4 1.5-minute passes making up each test, totaling 6–8 minutes of helicopter time on site during 40–60 minutes per test day (for details, see Grubb et al. 2007, tables 13–14). We began in 2006 testing the 800-m buffer distance, followed by 400-m, 200-m, and 100-m test distances. All flights were flybys, flown parallel to the nest cliff at the designated horizontal distance from the nest, at an altitude equal to or slightly above the nest elevation. Accurate flight paths were coordinated via previously arranged Global Positioning System (GPS) coordinates. Test helicopters were scheduled to fly past 4 nests per day, making 2 complete circuits with 2 passes per nest per circuit. We tested at 8 active nesting territories between 11 and 20 April 2006.

In 2007, we again tested 100-m, 200-m, 400-m, and 800-m horizontal distances with flybys, but we added 2 more aggressive test patterns, approaches, and popouts. During an approach, the helicopter flew straight toward the nest on a course perpendicular to the nest cliff, from a point 800 m in front of the nest to a point 800 m behind it, passing directly over the nest (0 m, horizontal distance) just above cliff height. During a popout, the helicopter flew on a course perpendicular to the nest cliff, from a point 800 m behind the nest to a point 800 m in front of it, passing directly over the nest (0 m, horizontal distance) just above cliff height, popping out suddenly from behind. Unlike flybys, approaches and popouts were only flown once during each circuit. We tested at 15 active nesting territories between 3 and 26 April 2007, including 6 territories from 2006 and 9 new territories.

Within limitations of practicality and unforeseen schedule modifications, we randomly assigned test distances among nesting territories. We also tried to avoid repetition of the same test distance at any given territory within the same season. Actual distances between the helicopter and nests sometimes deviated from planned distances because of miscommunication, errors in navigation points, and variable flight conditions. Where differences occurred, we reassigned deviant passes to the nearest planned distance category or we created a new category for the final analysis.

We measured sound events in terms of flat, or unweighted, one-third-octave-band levels. We used 2 sound metrics: 1) sound exposure level (SEL), which represents total sound energy recorded; and 2) 10-second average equivalent energy level ($LEQ_{avg\ 10\text{-}sec}$) for measuring ambient sounds (U.S. Environmental Protection Agency 1982, Delaney et al. 1999, Pater et al. 2009). To minimize potential extraneous disturbance, we attempted to place microphones and DAT recorders on the same elevational contour and at the same distance from the flight path as targeted nests, but at a sufficient distance and where possible out of the eagle's view. For details of sound metrics, sound instrumentation, and recording techniques, see Delaney et al. (1999; in press) and Pater et al. (2009).

To compare sound levels among the 4 helicopters flown near nesting golden eagles, we measured the 3 civilian aircraft under similar standardized conditions. Each was flown first at 92 m (300 feet) AGL and at an airspeed of 111 km/hr (60 knots), directly above the sound recording equipment, and then on a parallel flyby at the same altitude and speed, 100-m horizontal distance from the microphone. We designed this pattern to simulate the overhead and 100-m profiles flown by Apache helicopters during field tests. We were unable to record Apaches under the same standardized scenario as civilian helicopters because of other aircraft in the local flight pattern during our profiling attempt. We therefore used field data for comparison.

For all data summaries and analyses, we defined an observation or helicopter–golden eagle response data point as one helicopter pass near one eagle. Thus, we tallied one helicopter flying past an incubating eagle on the nest with a second eagle perched nearby as 2 observations, passes, or data points. For frequency distributions of test distances and eagle nest status, activity, and response by helicopter type, we tallied total observations for all helicopters. For specific results from Apache testing, we included only data from Apache trials. We defined specific variables to describe golden eagle nest status, ambient activities, and responses (Appendix). For most Apache data analyses, we grouped eagle responses into 3 or 4 categories: none and none observed combined into none (as it was unlikely we missed any significant flight responses); glance, look, and track combined as watch; and flatten and fly separate or combined as respond. To consolidate small or single samples into meaningful groups, we also grouped several recorded distances for all helicopters at 2 intervals: we combined 900 m and 1,200 m into 1,000 m, and we combined 1,800 m and 3,000 m into 2,000 m. Both of these groupings were well beyond the range of any expected or observed response so did not influence results. We analyzed variation in response rates by test week by combining the first and second trial weeks for all sites regardless of test year.

We used Excel 2002 (Microsoft, Redmond, WA) spreadsheet analytical tools and SPSS 10.1 (SPSS Inc., Chicago, IL) for data summaries, exploratory cross-tabulations, and *t*-test calculations (comparing test sample and population productivity means) and $\chi^2$ statistics (comparing test sample and population annual productivity, and % response between first and second test weeks). We created graphs in Excel and with Sigma Plot (Systat Software, Inc., Chicago, IL). We used Terrain Navigator 2001 (Maptech, Inc., Amesbury, MA) to plan helicopter flight paths; obtain GPS coordinates; print field and flight coordination maps; and facilitate distance measurements of flight paths, microphones, and observer positions after field tests. We tested for long-term variation in WPG operations with the Cox–Stuart trend test (Conover 1999).

## RESULTS

Multiple exposures to helicopters during our experimentation in 2006 and 2007 had no discernible effect on golden eagle nesting success or productivity rates, within the same year, or on rates of renewed nesting activity in the same territories the following year, compared with the reproductive performance of the rest of the surveyed population in northern Utah. In 2006, 8 of 12 (75%) manipulated nesting territories produced 1.25 young/active and 1.50 young/successful nesting territory, whereas for the greater northern Utah population, 76 of 101 (75%) surveyed nesting territories were active and produced 1.13 young/active ($t_{111} = 0.495$, $P = 0.622$) and 1.50 young/successful nesting territory (Keller 2006). In 2007, 14 of 17 (82%) manipulated nesting territories produced 1.29 young/active and 1.57 young/successful nesting territory. Eight of 12 (67%) 2006 active nesting territories were also active in 2007, compared with the rest of the surveyed population where 60 of 95 (63%) nesting territories active in 2006 also were active in 2007 ($\chi^2_1 = 0.107$, $P = 0.743$).

Golden eagles have been recorded in the TCA since at least the 1970s. Between 1981 and 2007, there were 4 years

**Table 2.** Wasatch Powderbird Guides (WPG) operating days and helicopter flights during the only years between 1981 and 2007 when presence of chicks confirmed active golden eagle nesting in the same Tri-Canyon Area drainage, Utah, USA. Nesting data are lacking for other years. Despite annual variation, WPG total operating days ($\bar{x}$ = 62.4) and helicopter hours ($\bar{x}$ = 210.6) have not increased since 1974 (Cox–Stuart trend test, $P$ = 0.371, 0.393, respectively).

| Yr | Nesting territory | WPG days[a] | WPG flights[b] | Golden eagle nesting |
|---|---|---|---|---|
| 2007 | MF | 29 | 1,508 | 8-wk-old chick, fledging probable |
| 2006 | MF | 36 | 2,836 | ≥1 chick fledged |
| 2000 | MF | 26 | 1,312 | 1 chick fledged |
| 1994 | MF | 37 | 1,972 | 1 chick, died, probable heat exposure |
| 1993 | SF | 16 | 292 | 1 chick fledged |
| 1992 | HB | 10 | 108 | 1 chick fell at fledging |
| 1989 | MF | 24 | 452 | 2 chicks fledged |
| 1981 | RB | 26 | 1,626 | 1 chick, fledging unknown |
| 8-yr total | 4 nesting territories | 10–37 operating days | 108–2,836 flights | 5 successful fledges<br>1 unknown outcome<br>2 unrelated mortalities |

[a] Days WPG flew in nest drainage, 15 Dec–15 Apr or through end of season.
[b] WPG runs in nest drainage × 4 (for each recorded run, one drop-off at top with one flight in and one flight out, plus one pick-up at bottom with one flight in and one flight out) × 1.7 (70% of runs have 2 lifts or helicopter loads, per drop-off and pick-up (R. Dassing, Wasatch Powderbird Guides, personal communication).

of no data, 15 years with documented presence of golden eagles (occupancy) but no unequivocal data on subsequent nesting attempts or outcomes, and 8 years (including 2 yr during our study) of active nesting confirmed by presence of chicks. During each of the 8 years of documented nesting in the TCA, WPG operated in the same drainage 10–37 days between 15 December and 15 April, flying 108–2,836 separate helicopter flights (Table 2). Between 1973 and 2007, WPG annually averaged 62.4 operating days (range = 24–86) and 210.6 hours of total helicopter time (range = 49.8–310.1), with no trends in either operating days ($P$ = 0.371) or total helicopter time ($P$ = 0.393) over the period.

Direct observations of WPG helicopters operating in the presence of golden eagles included 3 survey flights for the USFS, 2 controlled flybys, one simulated skier drop-off and pick-up; and 5 passive observations. Golden eagles seemed unaffected by heli-skiing operations. One pair of eagles, later successful, soared toward a maneuvering WPG helicopter. Another pair of eagles flew over an idling helicopter and landed on the same ridge <200 m away. They remained while the helicopter took off, skiers made their runs, and the helicopter returned for its pick-up flights below. Copulation on a ridge top perch, possibly by the same eagles, also occurred while a WPG helicopter circled in the drainage below on a different day. We never found an active nest with eggs or chicks for this pair. Two flys included one eagle from the nearby ridge top that later unhurriedly took off during the second pick-up flight and another of an immature male that flew after briefly landing for a prey delivery or nest exchange at another nest as our survey helicopter hovered <50 m away. The incubating female at this nest, and a second female at another similarly surveyed TCA nest, watched the helicopter without moving. Both pairs were successful in 2006 and active again in 2007.

We recorded 303 helicopter passes near ≥30 individual golden eagles, associated with 22 occupied nesting territories in northern Utah, 2006–2007 (Table 3). There were 227 experimental passes by Apache helicopters, with 89 on 4 test days over 2 weeks in 2006 and 138 on 8 test days over 4 weeks in 2007. In addition, we recorded 53 passes (directed, including survey flights, and passive or opportunistic) by WPG's 2 AStars, their Bell L4, and Cirque Lodge's Eurocopter. Cirque data resulted from 2 coordinated flybys and one popout at 2 nests along Cirque's regular route in Provo Canyon. Finally, we recorded 23 passive observations of civilian helicopters in the vicinity of nests being observed for the Apache trials.

We recorded 114 passes (38%) at nests during incubation; 147 (48%) occurred after hatching, and non-nesting eagles were exposed to 42 passes (14%; Table 4). At least 236 observations (78%) occurred when the attending eagle was incubating, brooding, or standing at the nest with young. Two of these eagles accounted for 6 of the 10 responses (3%) we recorded. There was no response on 217 occasions (72%), with some degree of watching the helicopter 76 times (25%). Four or 5 golden eagles accounted for 5 flattens and 5 flys at 5 nests during our 2-year project. The 5 flattens were exhibited by 2 eagles at different sites on 2 and 3 successive helicopter passes during the same trial in both cases. One non-nesting, 2 perched, and 1 returning (see Appendix) male eagle accounted for 4 of the 5 flys. Only one fly was by an attending eagle from the nest, when the helicopter seemed to cause a previously restless adult that had been shading a nestling for several hours to soar off. That eagle returned 2 hours later with prey and fed the chick. All responding pairs successfully fledged young except for a nest that fell for unknown reasons after hatching.

Of 227 Apache helicopter passes, nesting golden eagles showed no response 150 times (66%), watched the helicopter pass 69 times (30%), and responded 8 times by either flattening or flying from a nest (4%; Table 4). The watch response was made up of 25 (10%) glances, 33 (15%) looks, and 11 (5%) tracks. The 5 scheduled test flight horizontal distances from 0 m (approaches and popouts) to 800 m accounted for 157 (69%) of Apache passes, whereas unscheduled Apache passes at other distances totaled 70 (31%; Table 3). Replication frequency of planned test distances ranged between 20 and 47, with most passes occurring at 100 m, 200 m, and 400 m. Overall, 160 passes (71%) were at distances of ≤400 m, with 67 (29%) between

**Table 3.** Frequency distribution of distances for observations of helicopters near nesting golden eagles in northern Utah, USA, 2006–2007 (1 observation = one helicopter pass by one golden eagle).

| Distance or profile (m) | National Guard AH-64 Apache[a] | Wasatch Powderbird Guide | | Cirque EC130-B4[c] | Passing civilian helicopter | Distance subtotal |
|---|---|---|---|---|---|---|
| | | AS350-B3[b] | Bell L4[b] | | | |
| Approach[d] | 9 | | | | | 9 |
| Popout[e] | 12 | | | 1 | | 13 |
| 50 | | 1 | 3 | 1 | | 5 |
| 100 | 39 | 3 | 2 | 1 | | 45 |
| 200 | 47 | 6 | 2 | | 2 | 57 |
| 300 | 23 | | | | | 23 |
| 400 | 30 | 1 | | | | 31 |
| 500 | 16 | | | | | 16 |
| 600 | 9 | 2 | | | 1 | 12 |
| 700 | 4 | | | | 1 | 5 |
| 800 | 20 | 16 | | | 2 | 38 |
| 900[f] | 2 | | | | 1 | 3 |
| 1,000[f] | 4 | | 1 | | 6 | 11 |
| 1,200[f] | 1 | | | | 2 | 3 |
| 1,400 | | | | | 1 | 1 |
| 1,600 | | | | | 1 | 1 |
| 1,700 | | 12 | | | | 12 |
| 1,800[g] | 1 | | | | 2 | 3 |
| 2,000[g] | 9 | 1 | | | 3 | 13 |
| 3,000[g] | 1 | | | | 1 | 2 |
| Aircraft total | 227 | 42 | 8 | 3 | 23 | 303 |

[a] AH-64 Apache attack helicopter (Boeing Defense, Space & Security, Berkeley, MO), operated by the Utah National Guard, 211th Aviation Attack Helicopter Unit (West Jordan, UT).
[b] Eurocopter AS350-B3 (AStar; Eurocopter: Division of European Aeronautic, Defense and Space Company, Marignane, France) and Bell 206 L4 Long Ranger (Bell Helicopter Textron, Inc., Fort Worth, TX), operated by Wasatch Powderbird Guides (Snowbird, UT).
[c] Eurocopter EC130-B4, with fenestron tail rotor, operated by Cirque Lodge (Sundance, UT).
[d] Experimental helicopter flies straight toward nest location on a course perpendicular to nest cliff, from a point 800 m in front of nest to a point 800 m behind it, passing directly over nest just above cliff ht (0-m horizontal distance from nest as helicopter passes directly overhead).
[e] Experimental helicopter flies on a course perpendicular to nest cliff, from a point 800 m behind nest to a point 800 m in front of it, passing directly over nest just above cliff ht, popping out suddenly from behind (0-m horizontal distance from nest as helicopter passes directly overhead).
[f] We grouped AH-64 Apache observations at 1,000 m for subsequent analyses.
[g] We grouped AH-64 Apache observations at 2,000 m for subsequent analyses.

500 m and 3,000 m. All 3 flight responses occurred at $\leq$200 m and all 5 flatten responses occurred at $\leq$400 m. Otherwise, there was no pattern of variability across distance for absence of response (range = 46–100%) and watching (range = 17–54%).

Number of Apache helicopter passes at any given nest ranged between 7 and 26. We compared each of the 3 sites where eagles responded with 2–4 other sites having similar helicopter pass frequency, but we found no consistency in responsiveness, nor any evidence that responsiveness at these sites was related to helicopter pass frequency. Nesting status, however, did affect responsiveness as incubating eagles only exhibited varying degrees of watching the helicopter and never flattened or flew. Both flattening and flying only occurred when chicks were present. There was an apparent tendency for non-attending eagles ($N$ = 9) to watch less (11% vs. 31%) and be more apt to fly (11% vs. 3%) than their nest-attending mates ($N$ = 218), but comparative data were insufficient to establish the relationship statistically. We found no difference in golden eagle response between first exposures (60% no response, 34% watch, 6% respond, $N$ = 100) and subsequent helicopter passes (68% no response, 29% watch, 3% respond, $N$ = 197; $\chi^2_2 = 4.092$, $P = 0.129$). Yet, our analysis of responsiveness by test week showed absence of response increasing between the first (59%) and second (75%) test weeks, whereas watching (34% and 24%, respectively) and responding (6% and 1%, respectively) both declined ($\chi^2_2 = 32.167$, $P \leq 0.001$).

Sound level for all helicopters we tested decreased from overhead to 100-m horizontal distance (Table 1). The Apache was loudest at both test distances, whereas the Cirque Eurocopter, with its fenestron (enclosed) tail rotor, was quietest. Because decibels (dB) are a logarithmic measure and not linear, perceived loudness roughly doubles for every 10-dB increase in sound level. Therefore, the Apache helicopter used throughout our testing was approximately 2 times louder (approx. 9 dB) than a WPG AStar when overhead (108.3 dB vs. 99.0 dB, unweighted SEL) and at 100 m (105.7 dB vs. 97.2 dB, unweighted SEL). Ambient sound levels throughout field testing and helicopter profiling ranged between 44 dB and 48 dB (A weighted LEQ).

Frequency spectra for 5 Apache helicopter test profiles (100-m, 400-m, and 800-m flybys, approach, and popout; Fig. 1a) showed that sound energy from distant flights decreased more rapidly at mid- to higher frequencies (>100 Hz) than at lower frequencies (<100 Hz). For all distances and profiles, highest levels of sound energy occurred below approximately 100 Hz and thus were below or within the less sensitive reaches of a golden eagle's hearing sensitivity (Fig. 1b). Much of the helicopter's sound

**Table 4.** Frequency distribution of golden eagle nest status, activities, and responses for observations of helicopters near nesting eagles in northern Utah, USA, 2006–2007 (1 observation = one helicopter pass by one eagle; see Appendix for definitions).

| Golden eagle parameter | National Guard AH-64 Apache[a] | WPG[b] Cirque[c] | Passing civilian helicopter | Parameter subtotal |
|---|---|---|---|---|
| Nest status | | | | |
| Eggs | 84 | 13 | 17 | 114 |
| Young | 143 | | 4 | 147 |
| Non-nesting | | 40 | 2 | 42 |
| Eagle activity | | | | |
| Copulating | | 2 | | 2 |
| Incubating | 72 | 13 | 17 | 102 |
| Brooding | 102 | | 1 | 103 |
| Standing at nest | 12 | | 3 | 15 |
| Tending young | 5 | | 2 | 7 |
| Tending nest | 4 | | | 4 |
| Preening | 7 | | | 7 |
| Prey delivery | 2 | | | 2 |
| Nest exchange | 3 | | | 3 |
| Returning | 3 | 1 | | 4 |
| Perching | 7 | 5 | | 12 |
| Soaring, flying | 6 | 29 | | 35 |
| Out of view | 4 | 3 | | 7 |
| Eagle response | | | | |
| None[d] | 107 | 34 | 12 | 153 |
| None observed[d] | 43 | 11 | 10 | 64 |
| Glance[e] | 25 | 1 | | 26 |
| Look[e] | 33 | 4 | 1 | 38 |
| Track[e] | 11 | 1 | | 12 |
| Flatten on nest[f] | 5 | | | 5 |
| Fly[f] | 3 | 2 | | 5 |
| Helicopter total | 227 | 53 | 23 | 303 |

[a] AH-64 Apache attack helicopter (Boeing Defense, Space & Security, Berkeley, MO), operated by the Utah National Guard, 211th Aviation Attack Helicopter Unit (West Jordan, UT).

[b] Eurocopter AS350-B3 (AStar; Eurocopter: Division of European Aeronautic, Defense and Space Company, Marignane, France) and Bell 206 L4 Long Ranger (Bell Helicopter Textron, Inc., Fort Worth, TX), operated by Wasatch Powderbird Guides (Snowbird, UT).

[c] Eurocopter EC130-B4, with fenestron tail rotor, operated by Cirque Lodge (Sundance, UT).

[d] We grouped none and none observed for some analyses into none.

[e] We grouped glance, look, and track for some analyses into watch.

[f] We grouped flatten and fly for some analyses into respond.

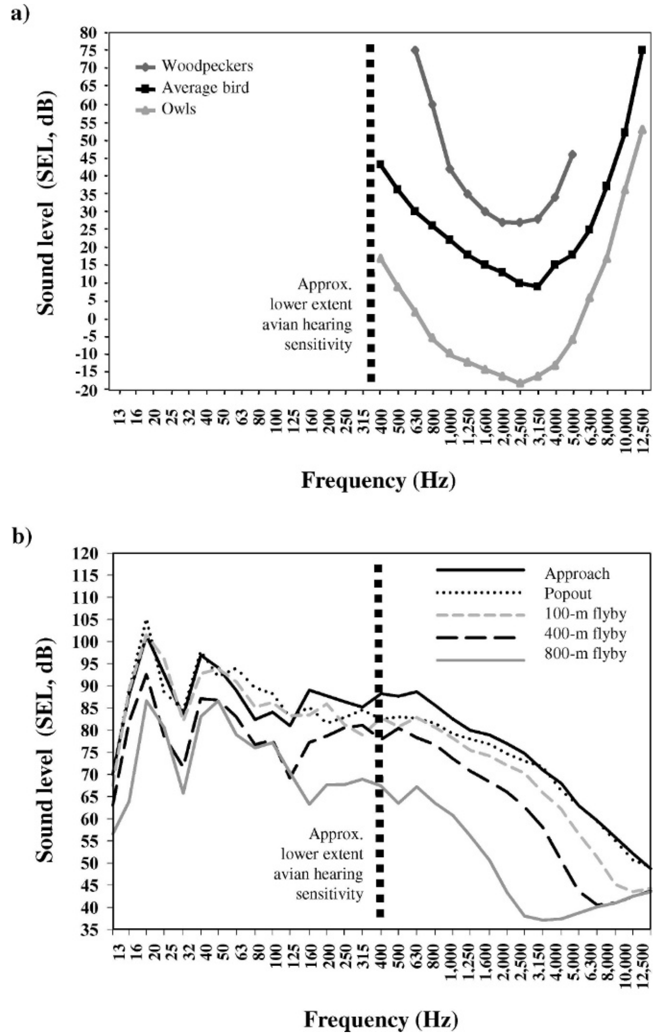


**Figure 1.** (a) Examples of avian audiograms (Pater et al. 2009) illustrating hearing sensitivity (unweighted sound exposure level [SEL]; decibels [dB]) and frequency range for a composite average of 7 orders of birds (Dooling 1980, Dooling et al., 2000), a composite average for owls (Trainer 1946, Konishi 1973), and a composite average for woodpeckers (Delaney et al., in press). (b) Unweighted SEL (dB) of Apache helicopters flying different test profiles and distances from nesting golden eagles in northern Utah, 2006–2007, with the approximate lower extent of avian hearing sensitivity indicated from a.

energy was at a lower frequency than golden eagles may readily hear. An analysis of sound level versus time from peak for an Apache approach and popout indicates that an approach was louder than a popout because sound of the approaching helicopter was not blocked by the nest cliff; however, as a result, a popout had a quicker (i.e., steeper) onset rate. After peak sound when the helicopter passed approximately overhead, the situation reversed, so that a popout was louder longer, decreasing more slowly than an approach whose departing helicopter sound was immediately buffered by the nest cliff.

Sound decreased with distance and most precipitously when flights were perpendicular to cliff and ridge lines. We recorded 90 Apache overflights at known distances from microphones. Sound level dropped off rapidly with increasing distance, falling from approximately 108.5 dB at 50 m to 81.3 dB at 1,000 m (unweighted SEL; Fig. 2). Nonetheless, during our Apache trials, golden eagles continued to exhibit normal ambient behaviors across the entire range of helicopter test distances: delivering prey between 0 m and 50 m; tending young from 100 m to >1,200 m; tending nests between 200 m and 800 m; preening from 200 m to >1,200 m; and soaring between 100 m and 400 m. Responses after hatching occurred between 300 m and 400 m (flattening) and 0 m and 200 m (flying). Only 39 recorded Apache overflights occurred when microphones were effectively positioned to yield representative sound levels at nests. Although sound levels ranged between 76.7 dB and 108.8 dB (unweighted SEL) and distances from 50 m to 800 m, we found no relationship between helicopter sound levels and corresponding ambient behaviors or limited responses (watching). Both occurred throughout recorded test ranges and seemed independent of dB level.

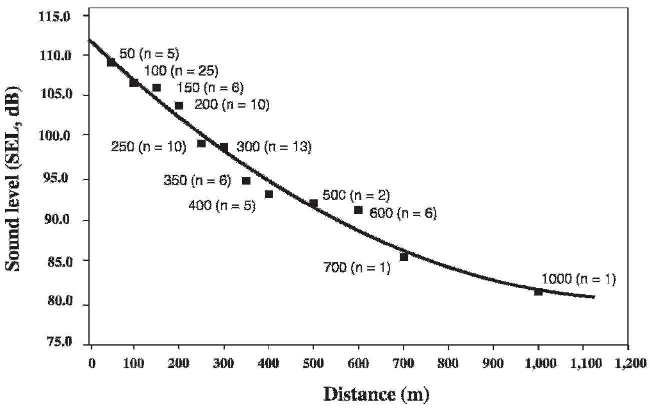


**Figure 2.** Inverse relationship (polynomial trend line) between sound level and distance, as illustrated by average, unweighted sound exposure levels (SEL, decibels [dB]) for 12 distances of Apache AH-64 military helicopters from field recording microphones during flights near nesting golden eagles in northern Utah, USA, 2006–2007.

## DISCUSSION

Wasatch Powderbird Guide helicopter operations did not negatively impact nesting golden eagles in the TCA because 1) there was minimal temporal and physical overlap between nesting golden eagles and WPG operations at higher elevations; 2) when there was simultaneous presence, golden eagles were not disrupted by WPG operations; 3) if nesting began while WPG was still operating, passing helicopters did not flush incubating golden eagles; and 4) our only recorded fly responses were after hatching, which at higher elevations did not occur until approximately 2–6 weeks after heli-skiing operations ceased.

Historical data indicate golden eagles have continuously occupied the TCA since at least the 1970s, despite exponential human population growth along the Wasatch Front with a corresponding increase in back country recreation, fueled by recent technological advances in winter sports equipment. The size, proximity, and outdoor orientation of the greater Salt Lake City–Wasatch Front human population almost certainly have a pervasive, underlying effect on all golden eagles nesting not only in the TCA but also throughout northern Utah. Continued presence of nesting golden eagles in the TCA during WPG's entire operational tenure, plus the simultaneous, rapid growth in local human population and recreational activity over the same period, suggest no long-term or detrimental effect, while also implying a potential pattern of tolerance, adaptability, and habituation. Other mitigating factors within the TCA included rugged, high-relief topography that provided inherent line of sight and sound buffering across intervening ridges. Nests in the TCA were also on tall cliffs or large escarpments, often below ridges where their natural placement provided physical separation from any helicopters landing nearby or skiers navigating adjacent runs.

Testing during incubation did not directly address the concern that helicopter activity during courtship and nest repair may disrupt or preclude subsequent nesting. However, if testing were attempted during prenesting, collecting meaningful data would remain improbable because golden eagles are seldom near their nests at that time. Although TCA nesting territories are regularly exposed to a variety of helicopters, most eagles at our lower elevation test sites were probably naive to helicopters, and none would have previously experienced anything comparable to the proximity and frequency of our test flights. Yet, in the few studies that have examined raptor responses at specific aircraft approach distances, flush rates (% flushed at each distance) were high if raptors were naive (Platt 1977), with >60% of birds flushed at ≤50 m (Carrier and Melquist 1976, Anderson et al. 1989). Some species are difficult to flush, particularly incubating and brooding bald eagles (Craig and Craig 1984, Fraser et al. 1985). Mexican spotted owls exposed to military helicopters flushed more frequently as distance to overflights decreased, but no flushes were recorded until after chicks fledged (Delaney et al. 1999).

Only considering years when chicks were present was a conservative way to assess potential WPG effects because hatching at elevations typical of the TCA nesting territories may not occur until approximately 2–6 weeks after the end of WPG's regular operating season. Also after hatching, there is an increasing risk to nesting success from an array of different threats (e.g., starvation, predation, disease, parasites; Newton 1979), independent of any prenesting stimuli. That golden eagles continue successfully nesting in the same drainages as WPG flights confirms that golden eagle productivity can be, at least for some pairs, unaffected by such activity. Because 4 nesting territories were successful during the 27 years of historical records, multiple individual golden eagles and pairs were likely exposed to WPG helicopter flights before and during their nesting.

Nevertheless, raptors are typically more susceptible to disturbance early in the breeding season when parents have little energy invested in the nesting process (Fyfe and Olendorff 1976, Awbrey and Bowles 1990). The tendency to flush from a nest seems to decline with experience (i.e., habituation), and individual responsiveness also declines as the breeding season progresses through its early to mid-stages (Knight and Temple 1986). Nesting bald eagles are less likely to flush once incubation begins; however, the pattern reverses later in the nestling cycle as nestlings mature and the requirement for nest attendance diminishes (Fraser et al. 1985). Bald eagles exposed to helicopters, jets, and light planes showed increasing alert and flight responses as the nesting season advanced. Distance between eagle and aircraft, duration of overflight, and number of aircraft or passes were the most important characteristics influencing bald eagle responses (Grubb and Bowerman 1997).

The lack of significant trends in WPG annual operating days and helicopter time, along with the continued presence of golden eagles over the years, contraindicate any major change in WPG operations having potentially affected nesting golden eagles in the TCA. We did not detect any relationship between annual fluctuations in either measure of WPG helicopter activity and those years of confirmed nesting success in the TCA. All our observations and data suggest local habituation or tolerance. Passing helicopters did not disrupt golden eagle nesting during any of our active testing and passive observations in northern Utah. We observed no detrimental or disruptive responses, and the only reactions beyond watching the helicopter occurred after hatching. Ellis (1979) described flattening as a head-down-crouch behavior most commonly occurring in response to an approaching person but also seen in response to a pursuing helicopter. In our study, incubating golden eagles, if they responded at all, did no more than watch, regardless of distance or flight profile of the test helicopter.

We interpreted most flys associated with both Apache and WPG helicopters as the aircraft precipitating an imminent departure, rather than eliciting a startled, avoidance reaction. However, exposure to human activities during times of low prey densities or periods of increased stress levels may result in nest failure. Normal perching, hunting, and flight behaviors within a military training area in Idaho were significantly altered during years of low prey densities (Schueck et al. 2001). Similarly, species on the periphery of their breeding range, elevationally or latitudinally, are typically more vulnerable to effects of environment, prey availability, and competition (Newton 1979). Because our results suggest little or no effect from WPG operations, we conclude these ecological factors were more likely limiting local Wasatch Front golden eagle productivity than were current levels of heli-skiing.

Acoustic startle is an innate behavioral and physiological response to a loud noise, with a rapid onset rate and routinely exhibited by higher vertebrates (Peeke and Herz 1973). At higher stimulus levels, the startle cannot be eradicated completely by habituation (Hoffman and Searle 1968). As an efficient reactionary mechanism for avoiding predators, some degree of startle is always likely after a sufficiently loud sound. For raptors, the most severe startles occur when a bird is approached within 10–50 m from above without warning (Fyfe and Olendorff 1976). Thus, the rapid onset of sound during our popout profile, coupled with the sudden appearance of the helicopter overhead, was expected to elicit a startle response; yet, none of the golden eagles we tested exhibited any alarm during these test profiles. Limited hearing sensitivity and some degree of preconditioning to high levels of human activity along the Wasatch Front are our only explanations for this unexpected lack of response.

With growing awareness of the pervasive implications of noise measurement comes the responsibility to use proper methodology, terminology, metrics, and technology to obtain meaningful results (Pater et al. 2009). Animals do not hear sound in the same way humans do. Therefore, it is critical to determine the approximate frequency range of the target species' hearing sensitivity for comparison with an appropriately measured, sound energy spectrum of the stimulus, to determine what portion of stimulus sound energy is likely affecting the target species. To establish cause-and-effect relationships amidst the wide array of variables affecting sound characteristics and propagation, stimulus sound must be recorded in the field simultaneously with behavioral response and in proximity to the target species. As our study shows, results from properly executed sound analyses may be subtle yet profound in their management implications.

## MANAGEMENT IMPLICATIONS

We found no evidence that special management restrictions are required to protect TCA nesting golden eagles from potential impacts of current heli-skiing operations in northern Utah. The lack of disruptive responses and detrimental effects on nesting success during our extensive and aggressive testing with the larger, louder Apache helicopters substantiates our conclusion. The demonstrated tolerance of TCA golden eagles to current levels of WPG operations meets the exception for helicopter buffers described in the National Bald Eagle Management Guidelines (U.S. Fish and Wildlife Service 2007). However, it would be inappropriate to apply the foregoing recommendation universally without first analyzing the circumstance-specific characteristics of any new situation. Important considerations include the type, level, and frequency of anthropogenic activity; effects of intervening topography and vegetation; potential habituation to existing activities; and the local density and distribution of the species in question.

Unorthodox scientific findings such as the surprising indifference of golden eagles to helicopters that we found in our study highlight a growing conundrum all too common in human disturbance–wildlife research. First, participating agencies and organizations must recognize species-, site-, and circumstance-specific research is prerequisite for effectively assessing any potential human impacts on wildlife. However, second and equally critical, when such research is successfully executed, those same responsible management entities should accept and incorporate scientifically valid results, whether or not those results are consistent with expectations or tradition. Continuing to manage otherwise undermines the integrity of resource management and leaves the resource more vulnerable to real threats in the future.

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## LITERATURE CITED

Anderson, D. E., O. J. Rongstad, and W. R. Mytton. 1989. Response of nesting red-tailed hawks to helicopter over flights. Condor 91:296–299.

Anderson, D. E., O. J. Rongstad, and W. R. Mytton. 1990. Home-range changes in raptors exposed to increased human activity levels in southeastern Colorado. Wildlife Society Bulletin 18:134–141.

Awbrey, F. T., and A. E. Bowles. 1990. The effects of aircraft noise and sonic booms on raptors: a preliminary model and a synthesis of the literature on disturbance. Noise and Sonic Boom Impact Technology, Technical Operating Report 12, Wright-Patterson Air Force Base, Dayton, Ohio, USA.

Boeker, E. L. 1970. Use of aircraft to determine golden eagle, *Aquila chrysaetos*, nesting activity. Southwestern Naturalist 15:13–17.

Bruderer, B. 1978. Collisions of aircraft with birds of prey in the Alps. International Bird Strike Committee, 13th Annual Meeting, Bern, Switzerland. <http://www.int-birdstrike.org>. Accessed 22 Sep 2009.

Carrier, W. D., and W. E. Melquist. 1976. The use of a rotor-winged aircraft in conducting nesting surveys of ospreys in northern Idaho. Journal of Raptor Research 10:77–83.

Conover, W. J. 1999. Practical nonparametric statistics. John Wiley & Sons, New York, New York, USA.

Craig, T. H., and E. H. Craig. 1984. Results of a helicopter survey of cliff nesting raptors in a deep canyon in southern Idaho. Journal of Raptor Research 18:20–25.

Delaney, D. K., T. G. Grubb, P. Beier, L. L. Pater, and M. H. Reiser. 1999. Effects of helicopter noise on Mexican spotted owls. Journal of Wildlife Management 63:60–76.

Delaney, D. K., L. L. Pater, L. D. Carlile, E. W. Spadgenske, T. A. Beaty, and R. H. Melton. In press. Response of red-cockaded woodpeckers to military training operations. Wildlife Monographs.

Dooling, R. J. 1980. Behavior and psychophysics of hearing in birds. Pages 261–288 *in* A. N. Popper and R. R. Fay, editors. Comparative studies of hearing in vertebrates, Springer-Verlag, New York, New York, USA.

Dooling, R. J., B. Lohr, and M. L. Dent. 2000. Hearing in birds and reptiles. Pages 308–359 *in* R. J. Dooling, R. R. Fay, and A. N. Popper, editors. Comparative hearing: birds and reptiles. Springer-Verlag, New York, New York, USA.

Ellis, D. H. 1975. First experiments with capturing golden eagles by helicopter. Bird Banding 46:217–219.

Ellis, D. H. 1979. Development of behavior in the golden eagle. Wildlife Monographs 70.

Ellis, D. H., and C. H. Ellis. 1991. Raptor responses to low-level jet aircraft and sonic booms. Environmental Pollution 74:53–83.

Ellis, D. H., C. H. Ellis, and D. P. Mindell. 1991. Raptor responses to low-level jet aircraft and sonic booms. Environmental Pollution 74:53–83.

Fraser, J. D., L. D. Frenzel, and J. E. Mathisen. 1985. The impact of human activities on breeding bald eagles in north-central Minnesota. Journal of Wildlife Management 49:585–592.

Fyfe, R. W., and R. R. Olendorff. 1976. Minimizing the dangers of studies to raptors and other sensitive species. Occasional Paper No. 23. Canadian Wildlife Service, Ottawa, Ontario, Canada.

Grubb, T. G., and W. W. Bowerman. 1997. Variations in breeding bald eagle responses to jets, light planes and helicopters. Journal of Raptor Research 31:213–222.

Grubb, T. G., D. K. Delaney, and W. W. Bowerman. 2007. Investigating potential effects of heli-skiing on golden eagles in the Wasatch Mountains, Utah. Report to Wasatch-Cache National Forest, Agreement No. 05-JV-11221607-237. Rocky Mountain Research Station, Fort Collins, Colorado, USA.

Grubb, T. G., and R. M. King. 1991. Assessing human disturbance of breeding bald eagles with classification tree models. Journal of Wildlife Management 55:501–512.

Hoffman, H. S., and J. L. Searle. 1968. Acoustic and temporal factors in the evocation of startle. Journal of Acoustical Society of America 43:269–282.

Holmes, T. L., R. L. Knight, L. Stegall, and G. R. Craig. 1993. Responses of wintering grassland raptors to human disturbance. Wildlife Society Bulletin 21:461–468.

Keller, K. R. 2006. Golden eagle nesting survey report for the central Utah study area, February–July 2006. Report to Utah Division of Wildlife Resources, Salt Lake City, Utah, USA.

Keller, K. R. 2007. Golden eagle nesting survey report for the central Utah study area, February–July 2007. Report to Utah Division of Wildlife Resources, Salt Lake City, Utah, USA.

Knight, R. L., and S. A. Temple. 1986. Why does intensity of avian nest defense increase during the nesting cycle? Auk 103:318–327.

Kochert, M. N., K. Steenhof, C. L. McIntyre, and E. H. Craig. 2002. Golden eagle (*Aquila chrysaetos*). Account 684 *in* A. Poole and F. Gill, editors. The Birds of North America, The Birds of North America, Inc., Philadelphia, Pennsylvania, USA.

Konishi, M. 1973. How the owl tracks its prey. American Scientist 61:414–424.

Mathisen, J. E. 1968. Effects of human disturbance on nesting bald eagles. Journal of Wildlife Management 32:1–6.

Newton, I. 1979. Population ecology of raptors. Buteo, Vermillion, South Dakota, USA.

Pater, L. L., T. G. Grubb, and D. K. Delaney. 2009. Recommendations for improved assessment of noise impacts on wildlife. Journal of Wildlife Management 73:788–795.

Peeke, H. V. S., and M. J. Herz. 1973. Habituation. Behavioral studies. Volume 1. Academic Press, New York, New York, USA.

Platt, J. B. 1977. The breeding behavior of wild and captive gyrfalcons in relation to their environment and human disturbance. Dissertation, Cornell University, Ithaca, New York, USA.

Postupalsky, S. 1974. Raptor reproductive success: some problems with methods, criteria, and terminology. Pages 21–32 *in* F. N. Hammerstrom, Jr., B. E. Harrell, and R. R. Olendorff, editors. Raptor research report no. 2. Management of raptors. Raptor Research Foundation, Vermillion, South Dakota, USA.

Richardson, C. T., and C. K. Miller. 1997. Recommendations for protecting raptors from human disturbance: a review. Wildlife Society Bulletin 25:634–638.

Salt Lake Travel and Visitor Center. 2007. Salt Lake Demographics. <http://www.saltlakecityutah.org>. Accessed 10 Oct 2007.

Schueck, L. S., J. M. Marzluff, and K. Steenhof. 2001. Influence of military activities on raptor abundance and behavior. Condor 103:606–615.

Steenhof, K., and M. N. Kochert. 1982. An evaluation of methods used to estimate raptor nesting success. Journal of Wildlife Management 46:885–893.

Steenhof, K., and I. Newton. 2007. Assessing nesting success and productivity. Pages 181–192 *in* D. M. Bird and K. L. Bildstein, editors. Raptor research and management techniques. Hancock House, Blaine, Washington, USA.

Steidl, R. J., K. D. Kozie, G. J. Dodge, T. Pehowski, and R. E. Hogan. 1993. Effects of human activity on breeding behavior of golden eagles in Wrangell-St. Elias National Park and Preserve: a preliminary assessment. Wrangell-St. Elias Research and Resource Management Report September 1993, No. 93-3: 1–16. National Park Service, Copper Center, Alaska, USA.

Trainer, J. E. 1946. The auditory acuity of certain birds. Dissertation, Cornell University, Ithaca, New York, USA.

Trimper, P. G., N. M. Standen, L. M. Lye, D. Lemon, T. E. Chubbs, and G. W. Humphries. 1998. Effects of low-level jet aircraft noise on the behavior of nesting osprey. Journal of Applied Ecology 35:122–130.

U.S. Census Bureau. 2000. United States Census 2000 Census briefs and special reports. <http://www.census.gov/main/www/cen2000.html>. Accessed 10 Oct 2007.

U.S. Environmental Protection Agency. 1982. Guidelines for noise impact analysis. Report No. 550/9-981-105. U.S. Environmental Protection Agency, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 2007. National bald eagle management guidelines. Department of Interior, U.S. Fish and Wildlife Service, Washington, D.C., USA.

U.S. Forest Service [USFS]. 2004*a*. Final Environmental Impact Statement: Wasatch Powderbird Guide Permit Renewal, U.S. Department of Agriculture-Forest Service, Wasatch-Cache and Uinta National Forests. Wasatch-Cache National Forest, Salt Lake City, Utah, USA.

U.S. Forest Service [USFS]. 2004*b*. Record of Decision–Wasatch Powderbird Guides Special Use Permit Renewal, U.S. Department of Agriculture-Forest Service, Wasatch-Cache and Uinta National Forests, Salt Lake, Davis, Morgan, Summit, Wasatch, and Utah Counties, Utah. Wasatch-Cache National Forest, Salt Lake City, Utah, USA.

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**Appendix.** Terminology used in describing nesting status, activities, and responses recorded during helicopter flights near nesting golden eagles in northern Utah, USA, 2006–2007.

| Term | Definition |
|---|---|
| Nest status | |
| Eggs | Incubation phase of nesting cycle. |
| Chicks or young | Nestling phase, between hatching and fledging. |
| Non-nesting | Any observed golden eagles not associated with an active nest. |
| Golden eagle activity | |
| Copulating, mating | When male mounts perched female briefly, then typically flies off. |
| Incubating | Low on the nest, warming and protecting eggs, performed by both members of nesting pair, but predominantly by the female. |
| Brooding | Higher in the nest than incubating, warming and protecting young chicks. Usually only occurs while young are very small. |
| Standing at nest | When attending adult remains on nest with chicks, but stands off to side. Common as chicks get older, or during warm weather. |
| Tending young | Includes feeding young when discernible, or otherwise "poking into center of nest" after hatching. |
| Tending nest | Includes "house cleaning" or removing old prey items from nest, plus manipulating nest materials. |
| Preening | Self-grooming activities including preening feathers, scratching, stretching, etc. |
| Prey delivery | An eagle returning to the nest carrying a prey item. |
| Nest exchange | When 1 eagle returns to nest and changes places with attending eagle, which then departs. Common during incubation. |
| Perching | Used for eagles not on nest, either second member of pair or eagles observed elsewhere. |
| Returning | Describes an eagle returning to an unattended nest, which often occurs when young are old enough to be left alone. |
| Soaring or flying | Usually an activity of second pair member near nest, sometimes both eagles, often associated with nest exchange, also applied to eagles observed elsewhere. |
| Out of view | Recorded when eagles in area immediately before or after, but out of observer's view during recorded event. |
| Golden eagle response | |
| None | No interest, reaction, response, nor any apparent deviation from previously observed ambient behavior. |
| None observed | Distinction for those times when eagle on nest not fully in view, or any other eagles were out of view. On nest, subtle movements may not have been discernible, but the absence of a flush or exaggerated body movements was clearly evident. |
| Glance | A brief, quick, literal glance, and immediately focusing attention elsewhere. Totally casual, uninterested response. |
| Look | A longer, more directed view, slower to change focus of attention. A response that reflects at least passing interest. |
| Track | A look that involves turning of head to follow stimulus movement. Suggests concentrated, focused attention, but indiscernible whether a result of boredom, fascination with the movement, or alert behavior. |
| Flatten[a] | Protective, defensive measure taken by a brooding or chick attending eagle standing on nest, where the eagle literally flattens out across nest, covers young, with head, tail, and body low, to the extent that it nearly disappears from a lateral viewpoint. |
| Fly | Taking flight from nest or perch, distinguished from a flush by lack of abrupt, startled, agitated avoidance behavior, or subsequent rapid, erratic flight. Most flys recorded during helicopter tests appeared to be result of helicopter precipitating an imminent departure. |
| Flush | Agitated, abrupt, startled, avoidance flight, typical avian response to disturbance. |
| Additional terms | |
| Nesting territory[b] | Area that contains, or historically contained, $\geq$1 nest within the home range of a mated pair; often includes the active nest and several alternate nests. |
| Nest | Specific structure where eggs are laid and chicks are raised. |
| Occupied[c] | Nesting territory or nest where eagles are present. |
| Active[c] | Nesting territory or nest where egg-laying, incubation, or both are confirmed, sometimes by the later presence of chick(s). |
| Successful[b] | Nesting territory or nest where chick(s) successfully fledge, or reach fledging age. |
| Fledging[b] | Fully feathered chick(s) successfully flying from nest on their own volition, without approach of an intruder. |
| Attending | Eagle on nest, or perched nearby active nest if only adult present. |
| Non-attending | Usually male, pair member not on nest, or observed elsewhere. |

[a] Head-down-crouch, Ellis (1979).
[b] Steenhof and Newton (2007).
[c] Postupalsky (1974).