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Efficacy of CPTH-treated egg baits for removing ravens

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Abstract:
Human-altered landscapes have provided resource subsidies for common ravens (*Corvus corax*) resulting in a substantial increase in raven abundance and distribution throughout the United States and Canada in the past 25 years. Ravens are effective predators of eggs and young of ground-nesting birds. During 2002–2005, we tested whether chicken egg baits treated with CPTH (3-chloro-p-toluidine hydrochloride) could be used to manage raven numbers in an area where raven depredation was impacting sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) and greater sage-grouse (*Centrocercus urophasianus*) populations in Nevada. We performed multiple raven surveys at a treatment site and 3 control sites and used videography to identify predators and estimate egg bait consumption. We detected reductions in raven abundances over time at the treatment site during all years of this study and did not detect reductions in raven abundances at control sites. Videographic observations of egg consumption indicated that the standard 1:2 ratio (1 raven removed/2 eggs consumed) substantially overestimated raven take because nontarget species (rodents) consumed some egg baits. The technique described here likely will be effective at reducing raven densities where this is the intended management action.

***Key Words*:** 3-chloro-p-toluidine hydrochloride, avicide, chicken egg baits, common raven, CPTH, *Corvus corax*, DRC-1339, human–wildlife conflicts, Nevada, wildlife damage management

Human-altered landscapes provide resource subsidies to common ravens (*Corvus corax*) that frequently lead to their increased reproduction and survival (Boarman 1993, Webb et al. 2004). Ravens often use electrical transmission towers, highway overpasses, and railroad trestles as nesting substrate (Boarman and Heinrich 1999), aiding reproduction in areas that lack natural nest sites. Ravens forage efficiently in agricultural fields (Engel and Young 1992*a*), landfills (Webb et al. 2004), lambing sites (Larsen and Dietrich 1970), rangelands (Knight 1984), and linear right-of-ways of electric power transmission lines (Knight and Kawashima 1993). Raven abundance has tripled in the past 40 years throughout North America (Sauer et al. 2004), and increased as high as 1,500% since the 1960s in portions of the western United States (Boarman 1993, Sauer et al. 2004).

In the Great Basin, ravens feed opportunistically on eggs and young of many birds and animals (Boarman and Heinrich 1999), including prairie grouse (*Centrocercus urophasianus*;Schroeder et al. 1999, Schroeder and Baydack 2001, P. S. Coates, unpublished data). Unnaturally high raven populations as a consequence of anthropogenic resource subsidies may cause "spillov-er predation" (Schneider 2001). Spillover predation occurs when raven abundance increases due to resource subsidies. As individual ravens move to and hunt for prey in adjacent landscapes, they cause unnaturally high predation rates (Kristen and Boarman 2003). Concern that subsidized increases in raven abundances are adversely affecting sensitive species is growing because ravens are effective predators of many threatened and endangered species (Boarman and Heinrich 1999).

Managers often rely on multiple methods to reduce raven predation including shooting, trapping, and poisoning, as well as habitat manipulation (Boarman and Heinrich 1999). Even where long-term management programs (e.g., natural habitat restoration) are carried out, managers often include short-term lethal programs to reduce raven numbers. Toxic compounds are often a method of choice for lethal control because of advantages of reduced labor (Conover 2002) and applications designed to target specific species. The compound CPTH (3-chloro-p-toluidine hydrochloride), or DRC-1339, is the only legal toxicant currently registered by the U. S. Environmental Protection Agency (EPA) for raven population control (Larsen and Dietrich 1970, Spencer 2002). A lethal dose of CPTH causes irreversible kidney necrosis (DeCino et al. 1966) resulting in a period of listlessness followed by death within 24–72 hours of ingestion (Cunningham et al. 1979). Lethal dosages vary substantially among avian species, and corvids are highly sensitive to CPTH (LD_{50} = 5.6 mg/kg; Larsen and Dietrich 1970). Other avian species found in shrub-steppe communities that are also highly sensitive to CPTH include red-winged blackbirds (*Agelaius phoeniceus*; LD_{50} = 1.8 to 3.2 mg/kg) and mourning doves (*Zenaida macroura*; LD_{50} = 5.6 to 10.0 mg/kg) (DeCino et al. 1966).

To target ravens and other corvids, managers inject CPTH into chicken egg baits and place baits where they are likely to be encountered by ravens but not by nontarget species that also are sensitive to CPTH effects from ingesting the compound (Spencer 2002). No cases of secondary poisoning by CPTH of raptors or mammals have been observed (Cunningham et al. 1979), most likely because of rapid degradation of CPTH following ingestion coupled with relatively low CPTH sensitivity of species that would typically scavenge raven carcasses. CPTH has been used to reduce abundance of other birds that were judged to be pests, including red-winged blackbirds (Blackwell et al. 2003), American magpies (*Pica hudsonia*; Guarino and Schafer 1967), European starlings (*Sturnus vulgaris*; Besser et al. 1967; Royall et al. 1967), American crows (*Corvus brachyrhynchos*; Boyd and Hall 1987) and herring gulls (*Larus argentatus*; Seamans and Belant 1999).

Many managers have had limited success in using CPTH in the field to remove ravens, perhaps because published descriptions of application techniques and their efficacy are lacking or have not been previously developed. Managers typically estimate the number of ravens removed by interpolating from number of egg baits that disappear from bait stations, assuming that missing egg baits have been consumed by ravens (Spencer 2002). A common estimate is that 1 raven is removed from the population for every 2 missing egg baits at a station (Spencer 2002).

Our objectives were to develop, apply, and measure the efficacy of using systematically placed chicken eggs treated with CPTH to remove ravens. From 2002–2005, the raven removal program was necessary to reduce their predation during the breeding season of a small, reintroduced population of sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) and a natural population of greater sage-grouse (*Centrocercus urophasianus*) in northeastern Nevada. Here, we describe the CPTH application technique and its effects on a raven population. We also used video surveillance to identify consumers of egg baits and to estimate the number of ravens removed from the population by quantifying consumed CPTH egg baits.

Study areas

We conducted systematic raven removal and raven surveys on transects that overlap a treatment site of approximately 10,000 ha located on the east side of the Snake Mountains in northeastern Nevada, USA (N 0670859, E 4599749, zone 11, NAD 83), during the springs of 2002–2005. The study area was chosen by Nevada Department of Wildlife (NDOW) based on efforts to establish a reintroduced, nascent population of sharp-tailed grouse (Coates and Delehanty 2006). NDOW, in cooperation with the U.S. Department of Agriculture, Animal Health Inspection Service, and Wildlife Services (WS) chose to remove ravens because they were thought to be a primary predator of sharp-tailed grouse nests. Their assumption was based on interpreting nest and egg remains following depredation during 1999–2001 (P. S. Coates, unpublished data). Dominant plant communities were shrub-steppe at lower elevations and mountain shrub at higher elevations. Several other potential egg predators occupying the study area included coyotes (*Canus latrans*), striped skunks (*Mephitis mephitis*), American badgers (*Taxidea taxis*), ground squirrels (*Spermophilus* spp.), American magpies, and American crows.

Methods

Raven surveys

We conducted transect surveys (n = 64; Table 1) following the technique of Garton et al. (2005). Surveys were conducted every 3–7 days at the treatment site between late March and late June during 2002–2005. This period coincided with the periods of egg-bait treatment and sage-grouse nesting. During 2004 and 2005, we con-ducted raven surveys (n = 60) every 3–7 days at 2 and 3 untreated (UNT) sites (no CPTH application), respectively, using the same standard protocol as the treatment site. The first (UNT-1), second (UNT-2), and third (UNT-3) untreated sites were located approximately 22, 37, and 53 km from the treatment site, respectively. We chose untreated sites located at distances >3 times the reported average foraging distance by ravens (6.9 km; Engel and Young 1992*b*). Our reason for spacing apart treated and untreated sites was to prevent transient ravens from traveling from untreated sites into the area of raven removal and thereby affecting numbers of ravens at untreated sites. This average raven travel distance was derived from the nearest studied population of ravens (southwestern Idaho), and was located in a similar shrub-steppe community.

All survey transects were a distance of 27 km during 2002–2003 and 20 km during 2004–2005. We established 25 and 33 survey points along each 20- and 27-km transect, respectively. Points along each transect were separated by 800 m. Using binoculars at each survey point, we searched for a 3-minute period and counted the number of ravens and other corvids, flying or perched. We avoided recounting individual ravens by keeping track of ravens previously counted as we moved from 1 survey point to the next. We indexed raven abundance by calculating the number of ravens counted per 10 km along transects. Our objective was to compare indices of raven abundance among and within sites through the sage-grouse nesting season and not to estimate raven population density. We did not correct for the probability of detecting ravens in relation to distance from transect. Using binoculars to scan the shrub-steppe, we were confident that ravens within the transect width (0–500 m) would be detected without difficulty, regardless of whether the ravens were perching or flying.

Because we used vehicles to move between points, we designated survey transects based on unpaved roads at the treatment and untreated areas. Vehicle-use along roads was approximately the same among sites. Also, we selected transects that intersected ≥1 sage-grouse leks (sage-grouse breeding grounds) at all sites. The treatment site transect also intersected a newly established sharp-tailed grouse lek.

During 2002 and 2003, WS personnel performed 10 surveys as standard operational protocol. We occasionally observed and recorded crows and magpies at the treatment area during raven surveys. However, observations of these species were rare, perhaps because of the remote location of the treatment site, and they were not included in data analyses.

CPTH application

Raven removal was carried out in conjunction with WS personnel. We followed standard operational procedures for preparation of eggs treated with CPTH (Spencer 2002). We hard-boiled 220 eggs/week by placing 100 raw eggs at a time in an egg basket and boiling them in water for 13–15 minutes. We then removed the eggs and allowed them to cool for several hours. Cooling eggs prior to applying CPTH prevents cracking and toxicant decomposition from heat exposure. Eggs were rubber-stamped with a warning skull-and-crossbones or marked with the word poison, as instructed on the CPTH label. After the eggs cooled, we used a 6.3 mm ratchet hex screwdriver to punch an injection hole at the end opposite the air cell. The injection hole must reach the center of the yolk with a diameter large enough to contain 1 ml of solution without spillage.

To prepare the CPTH solution, we complied with all precautionary statements and directions indicated on the CPTH label. We made a 2% CPTH solution by dissolving 2 g of CPTH concentrate in 100 ml of potable water warmed to 43°C. We injected 1 ml of 2% CPTH solution into each egg injection hole using a 5-ml syringe or a 1-ml pipette. Prior to placement of egg baits at the treatment site, we stored the eggs in an upright position without covering injection holes for 2–4 hours to allow absorption of the compound into the albumen and yolk of each egg and prevent spillage.

Every 7 days at the treatment site from late March to late June 2002–2005, we placed 2 egg baits on the ground/bait station every 250 m along a 27.5-km route. We placed a total of approximately 10,560 eggs (2,640/year) through the duration of the study. The egg bait route intersected the recently established population

TABLE 1. Linear regression analyses of common raven abundances throughout the nesting season of sharp-tailed grouse and sage-grouse at the treatment site, where we distributed egg baits treated with CPTH (3-chloro-p-toluidine hydrochloride), and 3 untreated sites (UNT-1, UNT-2, and UNT-3) in northeastern Nevada during 2002–2005.

Year	Treatment				UNT-1				UNT-2				UNT-3			
	n^a	r^{2b}	P^c	Trend	n^a	r^{2b}	P^c	Trend	n^a	r^{2b}	P^c	Trend	n^a	r^{2b}	P^c	Trend
2002	12	0.381	0.033	Decrease												
2003	15	0.428	0.008	Decrease												
2004	20	0.283	0.016	Decrease	9	0.502	0.033	Increase					10	0.192	0.206	Stable
2005	17	0.734	<0.001	Decrease	13	0.031	0.856	Stable	13	0.011	0.733	Stable	15	0.038	0.488	Stable

[a] Number of surveys conducted.
[b] Coefficient of determination.
[c] Probability values from regression analyses comparing raven abundance to the ordinal date.

of sharp-tailed grouse and sage-grouse leks. We positioned eggs upright to prevent spillage of any compound that may not have been completely absorbed into the egg. Also, we placed eggs directly on the ground between shrubs with no vegetation covering them. To facilitate consumption by ravens we did not use unnatural objects (e.g., platforms) because ravens can be highly neophobic (Heinrich 1988). Also, every year the treatment site was prebaited with nontoxic egg baits 2–3 times to habituate ravens to egg baits as a food source. Prebaiting took place for 1–2 weeks. Between 62–72 hours following placement of egg baits (both treated and nontoxic), we recorded the number of eggs depredated, missing, or undisturbed, and collected and disposed of all remaining eggs. No eggs were left in the environment for more than 2–3 days, and no eggs were reused at a later date.

To identify egg bait predators, we used 4 miniature cameras with video-recording systems to monitor a random sample of egg baits throughout the treatment period (n = 18, 2004; n = 28, 2005). Also, we used 4 cameras to video-monitor nontoxic egg baits (no CPTH treatment) at random locations throughout the untreated sites during the same dates used to video record eggs at the treatment sites. This allowed us to compare frequencies of egg bait predator consumption among sites. Video-monitored eggs at untreated sites also had injection holes and warning labels. These were the only eggs placed at the untreated sites to prevent supplementing raven diets with a large quantity of unnatural food and, thereby, influencing raven abundances by attracting ravens into untreated areas. Cameras (40 × 40 × 60 mm) were deployed approximately 1 m from egg baits in a nearby shrub and equipped with infrared night illumination (850–950 nm wavelength), which is not detectable by vertebrates (Pietz and Granfors 2000). A 20-m cable was buried and connected to a time-lapsed, continuous-recording VCR (Pietz and Granfors 2000). We allowed video systems to record continuously for 72 hours. To avoid bias in the encounter frequency of animals that rely on visual cues to locate nests, we used adhesive camouflage tape and vegetation for concealment of the camera (Herranz et al. 2002). To avoid olfactory-related biases (Harriman and Berger 1986, Whelan et al. 1994), we used rubber boots and gloves to mask human scent during camera installation.

Statistical analyses

We used PROC MIXED procedures (SAS Institute Inc., Cary, N.C.) to test if changes in raven abundance indices differed through time among the treatment site and control sites. Year was assigned as a random effect. Raven abundance indices recorded at the treatment site during prebaiting were not assigned as a treatment variable in the analyses because CPTH eggs were not yet placed at the site. Also, we performed simple linear regressions at each site using abundance indices as the response variable and ordinal date (number of days elapsed from January 1) as the explanatory variable. Where the slope of a best-fit regression line differed statistically from zero, we determined whether the relationship was positive or negative.

Results

Indices of raven abundance changed through time at the treatment site (Figure 1) differently than at the untreated sites (F = 3.77; df = 3,115; P = 0.12; Figure 2). Raven abundances declined substantially at the treatment site during each year of the study, whereas abundances remained stable or increased at the untreated sites (Table 1). In each of the 4 years, raven abundance indices declined to near zero by mid-June in the treatment area, regardless of inter-year variation in raven abundance indices during March. An increase in abundance through time was detected at UNT-1 during 2004 (t = 2.66; df = 8; P = 0.033; Figure 2).

Of the 2,640 eggs placed at the treatment site/year, we found 756 eggs missing in 2002; 1,432 in 2003; 721 in 2004; and 1,736 in 2005. We video-recorded a total of 42 eggs consumed during 2004–2005. At the treatment site, 2 of 22 (9%) consumptions were by ravens, while at untreated sites ravens were responsible for 18 of 20 (90%) consumptions. Other consumers were Wyoming ground squirrel (*Spermophilus elegans*) (n = 14, treatment site only), Piute ground squirrel (*S. mollis*) (n = 3, treatment site only), Great Basin pocket mouse (*Perognathus parvus*; n = 1, treatment site only), American magpie (n = 2, treatment site only), and domestic cattle (n = 2, untreated site only). All rodents completely consumed the egg baits. Using videography, we found 1:11 ratio of

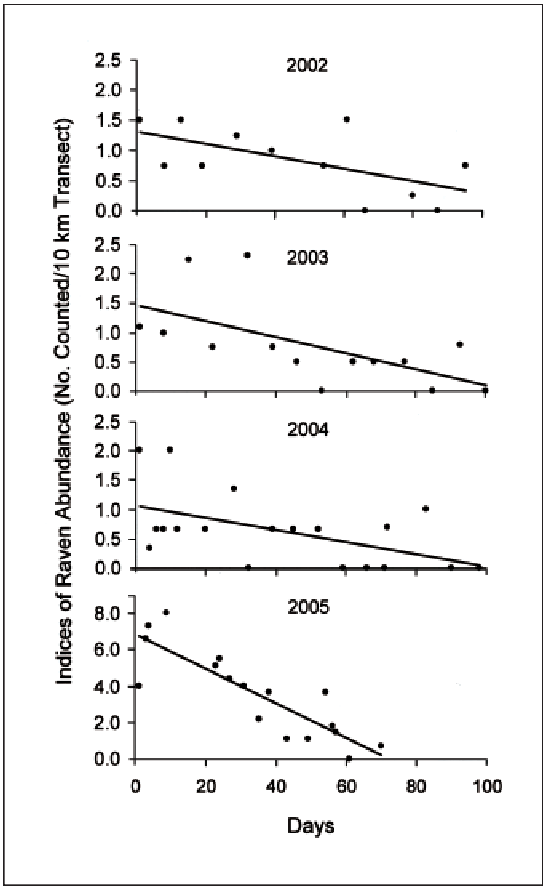

Figure 1. Indices of common raven abundance in relation to days of treatment using CPTH (3-chloro-p-toluidine hydrochloride), which was injected into chicken egg baits and placed in the environment for consumption by ravens every 7 days in northeastern Nevada during 2002–2005. Days of surveys were conducted from late March to mid-June, which encompassed the treatment period.

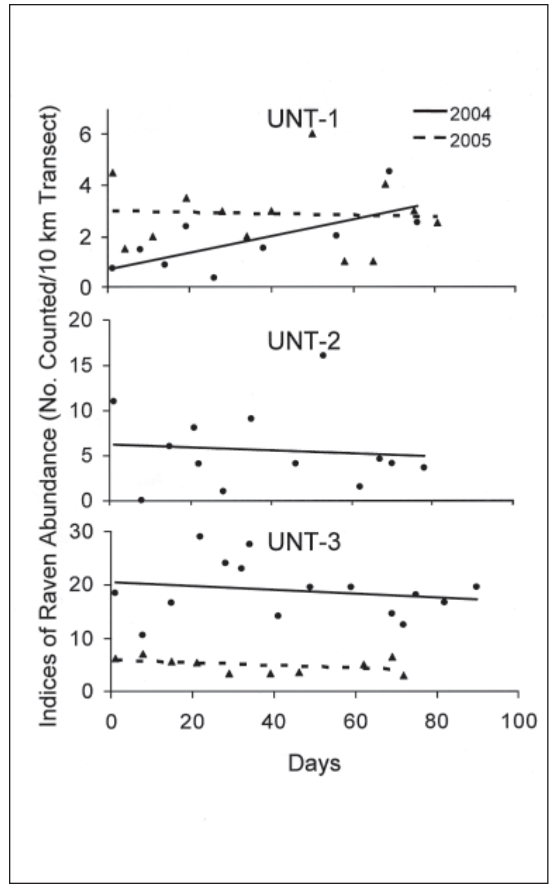

Figure 2. Indices of common raven abundance at 3 untreated sites in northeastern Nevada during 2004 (▲) and 2005 (●). UNT-1, UNT-2, and UNT-3 represent untreated sites (no CPTH application). Days of surveys were conducted from late March to mid-June.

raven consumption to missing eggs.

Discussion

We measured the effects of CPTH application using chicken egg baits on raven numbers in the wild and found substantial short-term reductions in raven population abundances associated with CPTH application. This is an important first test of the efficacy of CPTH at removing ravens using actual field conditions and untreated sites. It provides valuable information for making informed policy decisions. Removal of nest predators often increases nest success of ground nesting birds (Greenwood 1986, Garrettson and Rohwer 2001, Littlefield 2003), a necessary antecedent to recruitment and population renewal. Ravens have been documented to be important predators of sage-grouse nests at the treatment site (P. S. Coates, unpblished data) and elsewhere (Autenreith 1981, Schroeder et al. 1999, Schroeder and Baydack 2001), and removal of ravens may increase nest success of grouse (Batterson and Morse 1948).

Videography did not capture any nontarget species that are known to be at risk of fatality from CPTH effects consuming egg baits. However, ground squirrels, which are not known to be vulnerable to the dosage of CPTH we injected into eggs, were commonly observed consuming eggs. Ground squirrel LD_{50} values have not been described, but reported values of other rodents are relatively high. For example, mouse and white rat LD_{50} values were reported as 2,000 and 1,170-1,770 mg/kg, respectively (Clark 1986). The EPA

A raven is pictured in the act of taking an egg bait (left), then eating it (below).

approved CPTH for use primarily because of its rapid degradation and specificity to ravens and other corvids (raven's LD_{50} = 5.6 mg/kg; Larsen and Dietrich 1970). Therefore, chicken egg baits treated with CPTH to remove ravens from areas of raven damage appear to have low nontarget hazards, i.e., threat of affecting nonoffending animals (Conover 2002), something our finding supports. We did not observe dead animals or noticeable impairment of live animals of nontarget species due to the effects of CPTH. Furthermore, secondary poisoning hazards have not been observed in other studies and are thought to be unlikely to occur (Cunningham et al. 1979, Johnston et al. 1999). Although CPTH decomposes rapidly, it is important to remove all nonconsumed eggs from the field within 24–72 hours of placement to further reduce any unintended effects.

Recent evidence suggests that Richardson's ground squirrels (*Spermophilus richardsonii*), Wyoming ground squirrels, and Piute ground squirrels are not effective at depredating grouse eggs unless the eggs have been damaged (Coates and Delehanty 2004, Michener 2005). Our video observations indicate that ground squirrels used injection holes to open and consume our egg baits. Thus, while ground squirrels may not be important predators of grouse eggs (Michener 2005), they are an important predator of egg baits. We found that Wyoming and Piute ground squirrels were responsible for 71% of egg consumptions by species other than ravens.

Failure to consider ground squirrels as egg bait predators will lead to substantial error when using egg bait disappearance as a proxy for raven take. Egg bait consumption by ground squirrels will lead to overestimation of raven take, but the relationship has its own complexities. Ground squirrels were common at the untreated sites, but none were video-recorded consuming egg baits, as all squirrel consumptions took place at the treatment site. Ravens were primarily responsible for consumption (18 of 20 eggs) at untreated sites. Perhaps, in areas where ravens were abundant, they consumed egg baits prior to squirrels encountering and consuming them. Also, nocturnal rodents rarely consumed eggs. Egg baits were set out in morning hours providing ravens first access to bait relative to nocturnal mammals.

Alternatively, it is possible that ravens avoided treated eggs at the treatment site and not untreated eggs at the untreated sites. However, this seems unlikely because we found no videographic evidence of raven avoidance, and we measured a marked decline in raven abundance of the treatment site consistent with lethal consumption of egg baits.

Ravens and ground squirrels left similar signs following consumption of egg baits. For example, both species partially consumed eggs at the site and then moved eggs to another location, leaving fragmented egg shells at the bait site. Thus, ground squirrel and raven consumptions of egg baits were indistinguishable using diagnostic egg remains. Relying on more precise ratios derived from unambiguous identification techniques may be the most practical method to estimate raven removal. These estimates should be accompanied with weekly raven surveys in the treatment and untreated areas.

Our results suggest that CPTH application may cause short-term reductions in raven numbers without long-lasting effects on raven populations because of reoccupation of any vacant territories. Within raven populations, many nonbreeding ravens without territories are transient (Boarman and Heinrich 1999) and have been reported to travel 40–65 km in a day (Engel and Young 1992*b*, Heinrich et al. 1994). Furthermore, raven numbers rebounded each spring to abundances seen prior to CPTH application. Therefore, reapplication of CPTH must be made annually.

Prebaiting the treatment area with nontoxic eggs for approximately 2 weeks appeared to facilitate the consumption of egg baits by ravens. Because chicken eggs differ noticeably from wild grouse eggs and territorial ravens are often neophobic (Heinrich 1988), territorial ravens may be less likely to eat egg baits. Therefore, prebaiting may help to target territorial and nonterritorial ravens.

Indices of raven abundance at UNT-3 were substantially greater than those of the other 2 sites (Figure 1). Perhaps, the high abundances at UNT-3 were associated with greater availability of anthropogenic subsidies. UNT-3 was located <5 km from a landfill and surrounded by agricultural activity, while the other sites were >30 km from a landfill with less agriculture. Also, we observed more human-made structures, standing water, linear right-of-ways (e.g., roads and transmission power-lines), and livestock at UNT-3. Our findings are consistent with other recent evidence that indicates increases in raven populations are due to anthropogenic alterations in water, food, and nest sites (Boarman 1993, Knight and Kawashima 1993, Boarman and Heinrich 1999).

When applying CPTH chicken egg baits directly on the ground to remove ravens, we recommend avoiding the 1:2 ratio (ravens to missing eggs) that is currently used by managers to estimate raven take throughout the treatment period because it may substantially overestimate raven take, especially if ground squirrels begin consuming egg baits after an initial period of raven removal. A 1:2 ratio may more accurately reflect raven take in areas of concentrated raven populations without egg-bait consumption by nontarget species (e.g., treatment at sanitary landfills).

In our study, the frequency of egg predators that consumed egg baits differed among sites, where ravens were most responsible for egg depredation at untreated sites, and ground squirrels were most responsible for egg depredation at the treatment site. The initial week of treatment following prebaiting may have resulted in high raven take, but prolonged treatment did not appear to continue to remove ravens at high rates, even though eggs disappeared at high rates throughout the treatment period. Unfortunately, we were unable to estimate raven take using videography during initial treatment. However, following the first week of application, our estimated raven take was 1:11 ratio, rather than the 1:2 ratio that is currently used. A 1:11 ratio would lead to an estimated 69, 130, 66, and 157 ravens removed from the treatment site during 2002, 2003, 2004, and 2005, respectively. Even using a 1:11 adjustment, these values still appear high. Perhaps, continued research using unambiguous identification techniques will improve or confirm our estimates.

Also, ratios likely will change over time at treatment sites, perhaps resulting in a continuum of ratios, especially if the rate of raven take is continually decreasing and ground squirrel numbers are unaffected. Our sample sizes did not permit calculating multiple ratios through time, but further research regarding changing ratios would greatly improve our understanding of estimating raven take based on egg-bait consumption. Also, videography may lead to minor overestimation in raven take because ravens are known to take eggs and cache them for later consumption (Boarman and Heinrich 1999), and eggs may be consumed when CPTH is no longer viable or eggs are taken but not consumed.

In conclusion, using the technique described here, CPTH egg-bait treatment is effective in reducing raven abundance for short periods and in the immediate area of treatment. Lethal removal of predators is often an effective short-term management action for increasing nest success of ground nesting birds (Greenwood 1986, Garrettson and Rohwer 2001, Littlefield 2003). However, reducing anthropogenic resource subsidies of raven populations (Boarman 1993), and other long-term management actions, may be ultimately needed to reverse effects of spillover predation (Smith and Quinn 1996).

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