

DRC-1339 Egg Baits: Preliminary Evaluation of Their Effectiveness in Removing Ravens

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ABSTRACT: I measured the preliminary effects of chicken egg baits treated with DRC-1339 on removing common ravens for the purpose of reducing raven depredation of prairie grouse nests in northeastern Nevada. Greater sage grouse and Columbian sharp-tailed grouse are game species that are declining in distribution and abundance throughout their historic range. Reduced nest success due to egg depredation by ravens is thought to be an important cause of nest failure. Ravens are subsidized nest predators that have substantially increased in abundance throughout their range within the past 25 years. During 2002-2004, I removed ravens from a treatment site using chicken egg baits treated with DRC-1339 to protect sage grouse and a nascent population of reintroduced Columbian sharp-tailed grouse in northeastern Nevada. I performed raven surveys at the treatment site and 2 control sites, located 22 and 53 km northwest of the treatment site, to measure the effects of using DRC-1339. Preliminary analyses indicate chicken egg baits treated with DRC-1339 significantly reduced raven densities at the treatment site, and change in densities over time was different at the treatment site than the control sites ($F = 10.21_{2,59}$, $P < 0.001$). Also, anthropogenic resource subsidies (i.e., power-lines, roads, agricultural fields, and public landfills) appeared to influence raven abundance. If lethal removal of ravens is implemented as a short-term management action to protect areas from ecological or economical damage, the technique described here is valuable to managers.

KEY WORDS: avicide, chicken egg baits, Columbian sharp-tailed grouse, common raven, *Corvus corax*, DRC-1339, greater sage grouse, predator control

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INTRODUCTION

Avian populations are often limited by resource availability (Newton 1980, Lack 1966), and recent evidence demonstrates common raven (*Corvus corax*) distributions and abundances increase concomitantly with availability of nest substrate and food supply (Boarman 1993). Throughout North America north of Mexico, raven numbers have increased >200% from 1966 to 2003 (Sauer *et al.* 2004). Within the western United States, raven numbers have substantially increased since the mid-20th century (Boarman and Heinrich 1999). For example, numbers have increased >1,500% from the 1960s in the Mojave Desert (Boarman 1993, Sauer *et al.* 2004) and increases in abundances have been observed throughout the Great Basin Desert (Sauer *et al.* 2004), including northern Nevada. It appears that raven population increases are associated with the availability of anthropogenic resources, providing raven populations with subsidies that increase rates of reproduction and survival (Webb *et al.* 2004, Boarman 1993). For example, ravens use human-made structures as nest substrate where natural substrates are not available (Boarman and Heinrich 1999), including electrical transmission towers, highway overpasses, and railroad trestles (Steenhof *et al.* 1993). Also, ravens forage efficiently at sites influenced by human activity (Boarman 1993, Knight *et al.* 1993, Restani *et al.* 2001), including landfills (Webb *et al.* 2004), linear rights-of-way (Knight *et al.* 1995, Knight and Kawashima 1993), lambing ranges (Larsen and Dietrich 1970), agricultural lands (Engel and Young 1992a), and rangelands (Knight 1984).

Ravens are omnivores with a generalist diet, that opportunistically feed on eggs and young of animals

(Boarman and Heinrich 1999), including California condors (*Gymnogyps californianus*; Snyder *et al.* 1986), western snowy plovers (*Charadrius alexandrinus*; Page *et al.* 1995), least tern (*Sterna antillarum*; Avery *et al.* 1995), greater sandhill cranes (*Grus canadensis tabida*; Littlefield 2003), marbled murrelet (*Brachyramphus marmoratus*; Singer *et al.* 1991), Brunnich's guillemot (*Uria lomvia*; Gatson and Elliot 1996), desert tortoises (*Gopherus agassizii*; Boarman and Berry 1995), Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*), and greater sage grouse (*Centrocercus urophasianus*; Autenreith 1981, Batterson and Morse 1948). Evidence of detrimental effects on the reproduction of many threatened and endangered species associated with increased raven predation has been reported (Boarman 1993, Boarman and Heinrich 1999).

Increases in raven numbers within or adjacent to anthropogenic subsidies are thought to lead to "spillover predation" (Schneider 2001) and "hyperpredation" (Smith and Quin 1996). In the case of raven predation, spillover predation occurs when raven populations unnaturally increase in human-modified areas due to resource opportunities. Then, individuals move into the adjacent natural ecosystems and hunt for prey. Hyperpredation occurs when an indigenous prey species experience increased predation caused by unnaturally high raven numbers that are the result of abundant alternative food sources. Thus, coupled together, prey populations may experience increased predation in environments influenced by human activities. For example, in southeastern Idaho, ravens that used electrical transmission lines as nest substrate and communal roosts were found foraging in nearby agricultural fields and were also often observed

foraging in adjacent shrubland (Engel and Young 1992b).

Increased raven numbers also conflict with agricultural interests. For example, when ravens are overabundant, they cause damage to valuable agricultural crops (Salmon *et al.* 1986), conifer seedlings (Putman and Zasada 1985), and livestock (Larsen and Dietrich 1970, Hooper 1977). Therefore, unnaturally abundant raven populations may result in economic damage and the loss of many benefits that humans derive from natural ecosystems.

Management practices to reduce raven damage include shooting, trapping, manipulation of habitat, and the use of lethal and non-lethal chemical compounds (Conover 2002, Boarman and Heinrich 1999). Because raven abundances in most areas within their range are rapidly increasing and habitat restoration practices are generally long-term, many managers are considering using toxicants to prevent further depredation of wildlife of conservation concern.

The only toxicant currently registered by the United States Environmental Protection Agency (EPA) to be used to remove ravens lethally is DRC-1339, 3-chloro-*p*-toluidine hydrochloride (Spencer 2002, Larsen and Dietrich 1970). DRC-1339 is an avian-specific toxicant that causes irreversible kidney necrosis, resulting in the failure to excrete uric acid (DeCino *et al.* 1966). Following the ingestion of a lethal dose ravens experience a period of listlessness and a subsequent unconsciousness and death within approximately 24-72 hours (Cunningham *et al.* 1979). Laboratory tests provide evidence that DRC-1339 affects species differently, and ravens are highly sensitive to its effects ($LD_{50} = 5.6$ mg/kg; Larsen and Dietrich 1970), which allows the use of the compound to be species specific. Other avian species, reported in DeCino *et al.* (1966), are also highly sensitive to the effects of DRC-1339, and those that often occur in shrubsteppe communities include American crow (*Corvus brachyrhynchos*; $LD_{50} = 1.8$ mg/kg), red-winged blackbird (*Agelaius phoeniceus*; $D_{50} = 1.8$ to 3.2 mg/kg), mourning dove (*Zenaidura macroura*; $LD_{50} = 5.6$ to 10.0 mg/kg), and American magpie (*Pica hudsonia*; $LD_{50} = 5.6$ to 17.7 mg/kg). However, managers may effectively select species by injecting DRC-1339 into food items that specific species consume. Egg baits are often injected with DRC-1339 and placed in the environment to select corvids and prevent non-target species that are sensitive to DRC-1339 effects from ingesting the compound (Spencer 2002). Further species selection (i.e., ravens only) is a function of when and where the egg baits are placed in the environment, in addition to close monitoring of baits allowing modifications that reduce exposure of non-target species. Also, no symptoms of secondary poisoning of predators and scavengers have been observed (Cunningham *et al.* 1979), perhaps because of rapid chemical degradation.

DRC-1339 has been used to reduce population numbers of other species that are also susceptible to the compound and cause ecological or economical damage, including red-winged blackbirds (Blackwell *et al.* 2003), American magpies (Guarino and Schafer 1967), European starlings (*Sturnus vulgaris*; Besser *et al.* 1967, Royall *et al.* 1967), American crows (Boyd and Hall

1987), and herring gulls (*Larus argentatus*; Seamans and Belant 1999).

However, many managers have had limited success in using DRC-1339 to remove ravens and other corvids (Spencer 2002, J. O. Spencer, Jr., pers. commun.), perhaps because descriptions of application techniques and their efficacy have been lacking. My objectives were to develop, apply, and measure the efficacy of using systematically placed chicken egg baits treated with DRC-1339 to remove ravens, while simultaneously protecting a reintroduced, nascent population of sharp-tailed grouse and small population of greater sage grouse in northeastern Nevada, during 2002-2004. Here, I describe DRC-1339 application technique and present preliminary results of its effect on a raven population density.

METHODS

Study Areas

I removed ravens from a treatment site (TS) of approximately 120 km² at the base of the Snake Mountains in northeastern Nevada (N 0670859, E 4599749, zone 11, NAD83). The Nevada Department of Wildlife (NDOW), in cooperation with USDA APHIS Wildlife Services (WS), chose this area because ravens were found to be the primary nest predator, using subjective identification methods (i.e., diagnostic nest remains), of a recently reintroduced, nascent population of sharp-tailed grouse and small population of greater sage-grouse (S. Stiver, NDOW, unpubl. data).

During 2004, I surveyed ravens at 2 control sites at which no DRC-1339 treatment was applied. The first control site (CS1) was located approximately 22 km east of the treatment site, and the second site (CS2) was located approximately 53 km northeast of the treatment site. I chose control sites located at distances >22 km away from TS. These distances were >3 times the reported average of foraging distance by ravens (6.9 km, Engel and Young 1992b) and were intended to prevent transient ravens from traveling into the area of raven removal; thus affecting numbers of ravens at control sites. I used this reported average distance because it was derived from the nearest studied-population of ravens, which was also located in a similar shrubsteppe community in southwestern Idaho.

At all sites, dominant plant communities were shrubsteppe at lower elevations and mountain shrub at higher elevations. A variety of other potential egg predators were found at all sites, including coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), American badger (*Taxidea taxus*), ground squirrels (*Spermophilus* spp.), American magpie, and American crow.

Raven Surveys

To estimate raven densities, I conducted systematic, plot-along-transect sampling (Garton *et al.* 2005) every 3 to 7 days at TS during springs of 2002-2004 and at CS1 and CS2 during spring of 2004. I initiated surveys during late-March at TS, prior to raven removal activities, and ended mid-June, following the nesting and fledging stages of grouse reproduction. At CS1 and CS2, surveys ended during early June. During 2002-2003, WS

personnel carried out a subset of survey ($n = 10$) as standard operational protocol. Results of 5 surveys during 2003 by WS personnel were reported previously (Coates and Delehanty 2004). Surveys were conducted along 27-km transects during 2002-2003 and 20-km transects during 2004. Survey transects at all sites intersected a sage grouse lek route (an area of one or more traditional breeding grounds), and TS transect also intersected a newly-established sharp-tailed grouse lek. Every 0.8 km along each transect, I used binoculars to count the number of ravens observed in flight or on the ground within approximately 500 m, during a 3-minute searching period. There were 25 locations along each transect. I kept track of ravens between locations along transects to avoid recounting the same individuals.

Toxicant Application

I followed standard operational procedures by WS for preparation of eggs treated with DRC-1339; these methods have been described previously in detail (Spencer 2002). Briefly, I hard-boiled 100 eggs at a time by placing eggs into a wire basket and used a 22.8-L cooking pot and propane burner ($\geq 140,000$ BTU). I cooked eggs for 13-15 minutes or until they were hard-boiled. Eggs were removed and rubber-stamped with a warning label (i.e., skull and crossbones or “poison”). I allowed eggs to cool for several hours to avoid unwanted cracking while preparing the eggs for DRC-1339 application, and to prevent toxicant decomposition from heat exposure. Then, I used a 6.3-mm ratchet hex screwdriver to create an injection hole at the end opposite the air cell. The injection hole was designed to reach the center of the yolk with a diameter large enough to contain 1 ml of solution without over-spillage.

Before preparing the toxicant solution, I thoroughly read the entire label of DRC-1339 and carefully followed all precautionary statements and directions. I mixed the solution at a 2% concentration by dissolving 2 g of DRC-1339 in 100 ml of warm potable water. I used a 5-ml syringe to inject 1 ml of solution into each injection hole of each egg and was careful to keep eggs upright to prevent spillage. I allowed eggs to sit for 2 hours in an upright position before placement, to allow solution to absorb into the albumen and yolk, preventing spillage of the solution during placement.

I systematically applied the chicken egg baits treated with DRC-1339 to TS during springs of 2002-2004. I placed 2 egg baits at 110 feeding stations, separated by 250 m, along the raven removal route every 7 days. Egg baits were placed side by side with the injection holes facing upward to prevent spillage of solution that may not have previously absorbed. The 27.5 km raven removal route surrounded the location of recently re-established sharp-tailed grouse population (Coates and Delehanty 2006). I recorded depredated, missing, and undisturbed eggs 62-72 hours after placement, and I picked up and disposed of all partially depredated and undisturbed eggs.

I estimated 1 raven fatality for every 4 eggs that were completely depredated or missing from the feeding station. This formula was used as a conservative analogue to the standard 1:2 ratio used previously during WS operations (J. O. Spencer, Jr., USDA WS, pers.

commun.). My estimate accounted for recent observations of egg bait consumption by non-raven predators documented on video surveillance of egg baits in the field (Coates and Delehanty 2004).

Statistical Analyses

Based on raven counts at each transect, I estimated the number of ravens per 10 km². I performed simple linear regression analyses on the estimated raven densities through time. Raven density was the dependent variable and time was the independent variable. Therefore, I determined whether or not the slope of a best-fit regression line differed statistically from zero. If the slope differed from zero, I determined whether the relationship was positive or negative at each site. To test the slopes of raven numbers through time between the treatment site and controls, I used PROC MIXED procedures (SAS Institute Inc., Cary, NC) with year as a random factor.

RESULTS

Preliminarily, I found that raven densities changed through time at TS differently than at CS1 and CS2 ($F = 10.21_{2,59}$, $P < 0.001$). Also, raven densities significantly decreased every year at TS following DRC-1339 treatment with chicken egg baits, and no significant decreases were detected through time at the control sites (Table 1; Figure 1). Conversely, I detected a significant increase in raven densities through time at CS1 ($T = 2.66$, $P = 0.033$).

I conducted a total of 66 raven surveys (47 at TS, and 19 at CS1 and CS2) during 2002-2004. Surveys conducted during the pre-baiting period at TS were treated as controls in the analyses. During 2002, I conducted 12 surveys at TS (3 were controls). During 2003, 15 surveys were conducted at TS (2 controls). During 2004, I conducted 20 surveys at TS (4 controls) and 19 additional surveys at CS1 and CS2.

Approximately 7,900 chicken egg baits were placed at TS in 2002-2004. Of these, 750, 1,432, and 720 were missing from egg bait stations during 2002, 2003, and 2004, respectively. Using a 1:4 ratio of raven removal to egg loss, 189, 358, and 180 ravens were estimated as removed during 2002, 2003, and 2004, respectively.

Table 1. Results of simple linear regression analyses of raven densities during the nesting season of prairie grouse at a site treated with DRC-1339 chicken egg baits to remove common ravens and 2 control sites, located 22 and 53 km from the treatment site in northeastern Nevada, during 2002-2004. T and P represent the t-values and probability values, respectively. Double asterisks () represent a significant decrease in raven density over time ($\alpha = 0.05$).**

Year	Treatment		Control 1		Control 2	
	T	P	T	P	T	P
2002	-2.48	0.033**	-	-	-	-
2003	-3.12	0.008**	-	-	-	-
2004	-2.66	0.016**	2.66	0.033	-1.38	0.206

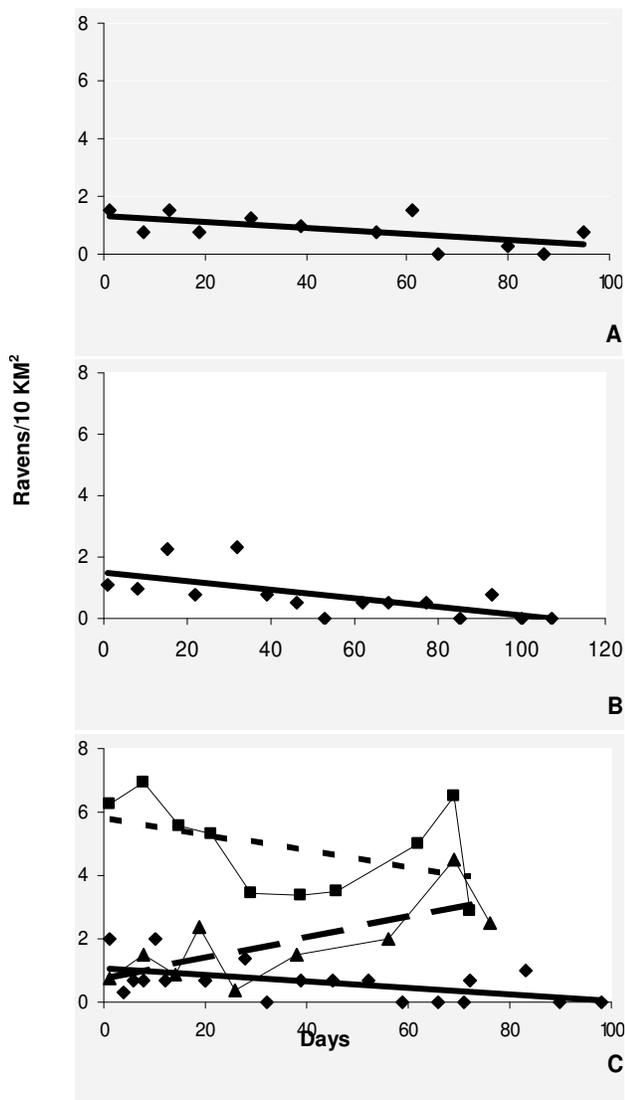


Figure 1. Densities of common raven populations at 3 sites in northeastern Nevada during 2002-2004. A and B illustrate population density changes at a site treated with DRC-1339 chicken egg baits used to remove ravens during 2002 and 2003, respectively. C illustrates population densities of ravens at the treatment site and 2 control sites during 2004. Control sites 1 and 2 are 22 and 53 km away from the treatment site, respectively.

DISCUSSION

Lethal removal of ravens with the purpose of increasing the densities of prey populations of conservation concern can be controversial. The question of whether lethal removal is an ethically appropriate action to reduce raven predation is a policy decision to be resolved by the public. My preliminary data suggest that systematic application of chicken egg baits treated with DRC-1339 is effective at causing a substantial short-term reduction in raven numbers. Therefore, the technique described here is valuable to managers if lethal removal of ravens is judged to be appropriate. Although lethal removal of overabundant ravens using DRC-1339 is currently practiced and techniques to prepare egg baits have been described in detail (Spencer 2002), this study is the first to

describe a systematic and effective technique to apply DRC-1339 to an area for the purpose of removing overabundant ravens. Undoubtedly, further studies will identify innovations and perhaps alternative approaches to DRC-1339 application.

Chicken egg baits treated with DRC-1339 to remove ravens from areas of raven damage appear to have low nontarget hazards (i.e., danger of killing the wrong species). The U.S. Environmental Protection Agency approved this toxicant primarily because of its high toxicity to ravens ($LD_{50} = 5.6$ mg/kg; Larsen and Dietrich 1970), rapid decomposition rates, and failure to accumulate in the food chain (Conover 2002). In addition, secondary poisoning hazards have not been observed and are unlikely to occur (Cunningham *et al.* 1979). Although DRC-1339 decomposes rapidly, it is important to pick up all non-consumed eggs within 24-72 hours of placement to further reduce unintended effects.

In this study, treatment of the protection site at least once per week during the nesting period of grouse appeared to be important to effectively reduce the raven population. Also, predator movement during the nesting season of prey often results in occupation of empty territories of predators soon after they are removed (Greenwood 1986) and the re-occupation of territories may nullify any population reduction produced by the removal action (Conover 2002). It is known that many non-breeding ravens do not occupy territories and are transient (Boarman and Heinrich 1999). Generally, ravens were absent from TS for approximately 5 days following DRC-1339 application and were subsequently observed in small numbers until reapplication. Presumably, transient ravens were re-occupying territories in which the original occupants had been removed. The application of DRC-1339 is a treatment to temporarily reduce raven numbers for the purpose of temporarily reducing nest predation. Because ravens appear to re-occupy territories soon after treatment, it appears that DRC-1339 is effective at short-term reduction in raven densities, perhaps allowing the accomplishment of management objectives (i.e., increased nest success), without long-lasting effects on raven populations. In addition, because ravens are known to be highly neophobic (i.e., fear novel food items) (Heinrich 1988) and chicken egg baits differ from wild bird eggs, it appeared to be important to pre-bait with non-toxic eggs for at least 2 weeks to facilitate the consumption of chicken egg baits (Spencer 2002).

Raven density at CS2 was substantially greater than the other 2 sites (Figure 1). Perhaps the high density at CS2 was associated with greater availability of anthropogenic subsidies. For example, it is known that nesting availability and food supply allows growth in avian populations (Newton 1980, Lack 1966), and recent evidence suggests that human-induced alterations in water, food, and nest sites have caused significant increases in raven populations throughout the Mojave Desert, California (Boarman 1993, Boarman and Heinrich 1999). CS2 was located <5 km from a landfill and was surrounded by agricultural areas. The other survey areas were >30 km from the nearest landfill. Also, at CS2 I observed relatively higher numbers of human-

made structures, standing water, linear rights-of-way (i.e., roads and transmission powerlines), and livestock, which have been shown to increase raven numbers (Boarman and Heinrich 1999, Knight and Kawashima 1993).

Studies support lethal removal as an effective short-term action for increasing nest success and population densities of prey species (e.g., Littlefield 2003, Greenwood 1986, Duebbert and Lokemoen 1980). If prey populations are severely affected by overabundant raven numbers and near extirpation due to increased predation, then short-term actions (i.e., avicide treatment) may show to be an effective way to increase reproduction of prey. However, long-term management actions are most likely also needed ultimately to reverse effects of hyperpredation (Schneider 2001) and spillover predation (Smith and Quinn 1996). Although lethal removal of predators may be effective in the short-term, it may not be associated with long-term successes (Beauchamp *et al.* 1996). Perhaps the most effective long-term actions are those that alter the root cause for population increases, such as reducing the availability of resource subsidies. Thus, DRC-1339 egg bait application to remove overabundant ravens may be valuable to give prey populations a temporary reprieve from predation, allowing increased reproduction, but should be accompanied by long-term actions designed to reduce increased predation effects.

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