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Note

Visual marking of ground nests might attract corvids

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Abstract: For ground-nesting birds such as waterfowl, estimating nest survival is a crucial step in assessing population dynamics, and marking nests facilitates continuous monitoring. A conventional method for marking ground nests is to use an inconspicuous rod at the nest bowl and a wooden lathe 10 m away. Nests are visually marked to allow for greater efficiency when revisiting nests and to facilitate subsequent nest searching sessions. Anecdotal evidence suggests that common ravens (*Corvus corax*) and American crows (*C. brachyrhynchos*) might learn to recognize these nest markers, resulting in artificially inflated rates of nest predation. In 2017 in central Alberta, Canada, we compared fates of nests marked with the conventional lathe-rod combination versus only a rod. We also tested the prevalence of corvid predation of marked nests in areas with and without high observations of corvid activity, using data from a study of dabbling duck (*Anas* spp.) nest survival. Our results suggest that marking nests with a lathe can increase predation by corvids and that nests marked with a rod only were more likely to hatch. Evaluation and use of alternate nest-marking methods would be beneficial for future studies of ground-nesting birds in areas where corvids are common. Our work highlights the importance of re-evaluating the efficacy of well-established field methods.

Key words: Alberta, *Anas* spp., *Corvus* spp., investigator effects, nest marking, nest predation, nest searching, nest survival, waterfowl

Field studies of nest success provide data integral to the management of ground-nesting birds like waterfowl and grouse and have been conducted since at least 1966 (Higgins et al. 1969). Field techniques for monitoring upland duck nests involve marking nests with flagged willow stakes or wire survey flags 4 m from the nest (Klett et al. 1986). Contemporarily, a method for marking nests involves placing an inconspicuous thin metal rod approximately 0.5 m tall at the nest bowl (Figure 1) and a painted wooden lathe (Figure 2) 10 m from the nest in a standard direction (Garrettson and Rohwer 2001).

Observer effects can negatively affect nest survival, particularly in subsequent years of a study when territorial predators have had time to learn investigator patterns and form search images for nest markers (Picozzi 1975, Buler and Hamilton 2000). Reducing the frequency of nest visitation by investigators can lower predation risk, but formation of search images based on nest markers by corvid species is a common challenge that has proven difficult to mitigate. For example, Rollinson and Brooks (2007) provide evidence that painted turtle (*Chrysemys picta*) nests marked with Popsicle™ sticks experienced higher rates of predation by common ravens (*Corvus corax*; ravens) and American crows (*C. brachyrhynchos*).

In some cases, observer effects might positively bias nest survival (Weidinger 2008, Ibáñez-Álamo et al. 2012). For example, nest cameras used at low density have been associated with higher nest survival, likely because they deter neophobic predators (Richardson et al. 2009). In other cases, marking nests appears to have no effect on nest predation (e.g., Zámečník et al. 2018 found that result using bamboo poles). Galbraith (1987) found no negative effect of marking lapwing (*Vanellus vanellus*) nests with short garden stakes, but lapwings display defense behaviors toward avian predators (Dyrcz et al. 1980). In some cases, what might be perceived as investigator-induced predation resulting from nest markers could be the result of high nest densities (Götmark 1992). Evidence for the effect of nest markers is

Figure 1. Trail camera photograph of 2 American crows (*Corvus brachyrhynchos*) at a duck (*Anas* spp.) nest near Bashaw, Alberta, Canada in 2016, with the rod used to mark the nest visible on the right. Trail camera was a Reconyx HC500™ (Holmen, Wisconsin, USA).

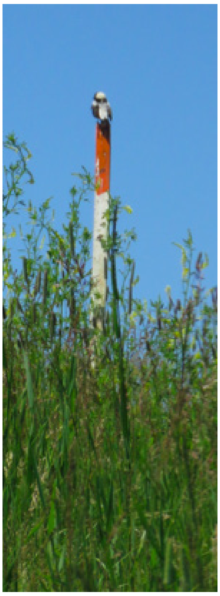

Figure 2. A painted lathe used to mark upland duck (*Anas* spp.) nests near Bashaw, Alberta, Canada with a bobolink (*Dolichonyx oryzivorus*) perched on top. Occasionally field researchers observed corvids using the lathes as perches, and lathes often collected avian excrement (*photo courtesy of E. O'Donovan*).

mixed (Ibáñez-Álamo et al. 2012), and the effect of nest markers is often conflated with observer activity. In our experience, observer activities of nest searching, installing markers, and visiting nests acted as cues to corvids to investigate nest markers, so it can be difficult to separate the effect of nest markers and observer activity.

There is a need to compare the effects of different nest-marking methods on the success of upland duck nests. These nests are cryptic and often found at high densities, and visually marking them reduces investigator search time and thus disturbance, reduces the chance of investigator damage to eggs, and facilitates multiple nest searching sessions. Here we highlight the possibility that common visual nest markers might attract crows and ravens, resulting in increased nest predation, and discuss alternative options.

In the final year of a 2-year study evaluating the removal of avian and mammalian predators on upland duck nest success (Blythe and Boyce 2020), we observed increased interest in investigators by corvids and conducted a post-hoc analysis. Based on field observations, we suspected that nests in some of our study sites were affected by artificially high predation from crows and ravens facilitated by recognition of nest markers. Observer activity also could have served as an attractant. We grouped crows and ravens (corvids) because both were observed regularly and both were suspected of contributing to nest loss, though we do not have data quantifying the degree to which each species contributed. Field technicians reported being repeatedly followed and watched by corvids at the same sites (deemed high-corvid activity [high-CA] sites) and not at other sites (deemed typical corvid activity [typical-CA] sites). Black-billed magpies (*Pica hudsonia*) did not display similar behaviors so were not included.

Our objective was to evaluate the effect of nest markers and perceived interest by corvids in investigator activities on duck nest success. We tested the null hypothesis that nest success would not differ between nests marked with a lathe-rod combination and a rod only. We predicted that nests marked with a rod only would be more likely to hatch because we expected corvids were recognizing lathes. We did not test the treatment of no nest marker because upland duck nests are cryptic and absence of any marker would increase the incidence of accidental trampling (Galligan et al. 2003). Also, we tested the null hypothesis that nests in areas where investigators regularly observed corvids watching and following them while carrying out nest research would have the same probability of hatching as nests where those behaviors were not regularly observed. We predicted that nests in areas where corvids showed interest in investigators would

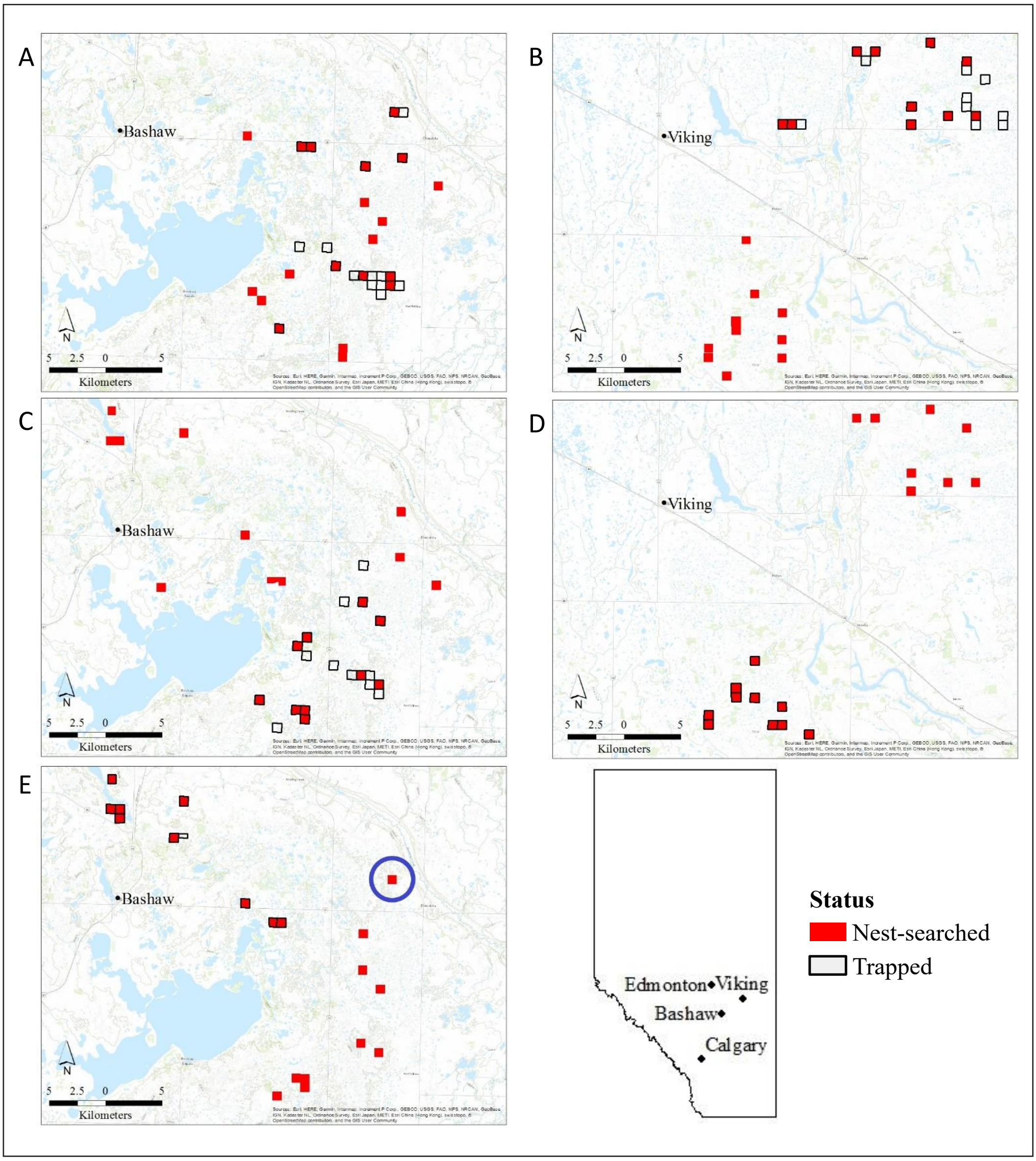

Figure 3. Maps of Bashaw and Viking study areas in Alberta, Canada from Blythe and Boyce (2020), 2015–2017: (A) Bashaw 2015 (pilot year), (B) Viking 2016, (C) Bashaw 2016, (D) Viking 2017, and (E) Bashaw 2017. The circled quarter section in (E) was the high-corvid activity area with a nest-marking intervention.

have lower success than those in areas where corvids did not display interest. To test this expectation, we relied on nest-site evidence to infer predator species.

Study area

We searched for and monitored duck nests at 2 study areas in the central Alberta parklands, near the communities of Bashaw (52.5857°N, 112.9663°W) and Viking (53.0971°N, 111.7755°W) in 2016 and 2017. Both study areas occur within a fragmented agricultural landscape characterized by rolling hills, numerous permanent and ephemeral wetlands, and stands of trembling aspen (*Populus tremuloides*). Land is partitioned into quarter section (~64.75 ha) parcels and most is privately owned. The landscape is fragmented by a high density of linear features including a 1.6-km by 1.6-km road network. Nests were monitored in upland areas and were typically found in grass, predominantly crested wheatgrass (*Agropyron cristatum*), common timothy (*Phleum pratense*), and other agricultural species. Other nest site vegetation included alfalfa (*Medicago sativa*) and regenerating aspen.

Nest predators routinely observed on the study areas included American crows, common ravens, and black-billed magpies. Other nest predators occurring in our study areas were striped skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), Franklin's ground squirrels (*Poliocitellus franklinii*), 13-lined ground squirrels (*Ictidomys tridecemlineatus*), American badgers (*Taxidea taxus*), long-tailed weasels (*Mustela frenata*), short-tailed weasels (*Mustela erminea*), American mink (*Neovison vison*), California gulls (*Larus californicus*), and ring-billed gulls (*L. delawarensis*). Nest predators notably absent from our study areas include rats (*Rattus* spp.) and egg-eating snakes (Russell et al. 2000, Bourne 2015).

Methods

During 2 nesting seasons, we monitored fates of upland-nesting ducks as part of a study evaluating the efficacy of predator removal to increase nest success (Blythe and Boyce 2020) and habitat associations with nest predation risk (Blythe 2019). Coyotes, skunks, and corvids (crows, ravens, and magpies) were the only predators removed in notable numbers (see supplemental material in Blythe and Boyce 2020 for removal data). Dabbling ducks were the focus of this research and included mallards (*Anas platyrhynchos*), northern pintails (*A. acuta*), northern shovelers (*A. clypeata*), blue-winged teals (*A. discors*), American green-winged teals (*A. crecca carolinensis*), gadwalls (*A. strepera*), and American widgeons (*A. americana*). At both study sites, 20 quarter sections were divided into 2 treatment groups: control and predator removal, separated by a minimum of 3 km. Predator removals were annually transposed, so that a quarter section that was a control in 2016 had predator removal in 2017, and vice versa (Blythe and Boyce 2020; Figure 3). For this study, we compared effects of nest marking between sites that were spatially paired (same quarter sections as the previous year), temporally paired (different quarter sections that were nest searched at the same time), and paired predator treatment (quarter sections that simultaneously shared the same predator treatment: predator removals or control). We nest searched each quarter section 2–3 times between May 1 and July 15 of each year using the chain-drag method (Higgins et al. 1969, Klett et al. 1986). In 2016, we marked nests by placing an unpainted, flexible wire rod (1–3 mm in diameter and approximately 0.5 m in height; Figure 1) at the edge of the nest bowl and a painted wooden lathe 10 m to the north (Figure 2). In 2017, we changed the placement of the lathe to a variable direction and distance (10–20 m) from the nest at both study areas, in response to anecdotal accounts of crows recognizing lathes in subsequent years of other studies (J. Brice, Delta Waterfowl, personal communication). Nest fates were determined from eggshell evidence (Klett et al. 1986); nests were considered successful if at least 1 egg hatched and failed if nests were either depredated or abandoned with or without evidence of predator activity. Nests destroyed or abandoned because of investigator influence (Blythe and Boyce 2020) were excluded from analyses. For these analyses, we used only hatched or depredated nests, and we treated nests that were abandoned as depredated if the hen was killed at the nest by a predator.

In 2017, 2 areas stood out because of observations of higher-than-normal corvid activity: all quarter sections ($n = 8$) in the Viking study area where no predator removal was occurring and 1 quarter section in the Bashaw study area (also no predator removal occurring; Figure 3). Corvid activity categorization was qualitative and based on repeated field observations occurring in the second year of a study not initially intended to address corvid interest or nest marking. Observations included corvids following and watching investigators during nest searching and nest checks. This behavior occurred repeatedly at high-CA sites and was consistently absent from typical-CA sites. High-CA sites at both Bashaw and Viking appeared to be experiencing higher than normal nest mortality during data collection, and predation was perceived to be from corvids. On the Bashaw study area, nest marking was altered midway through data collection in an attempt to reduce the ability of corvids to form search images based on nest markers; in Viking, no change

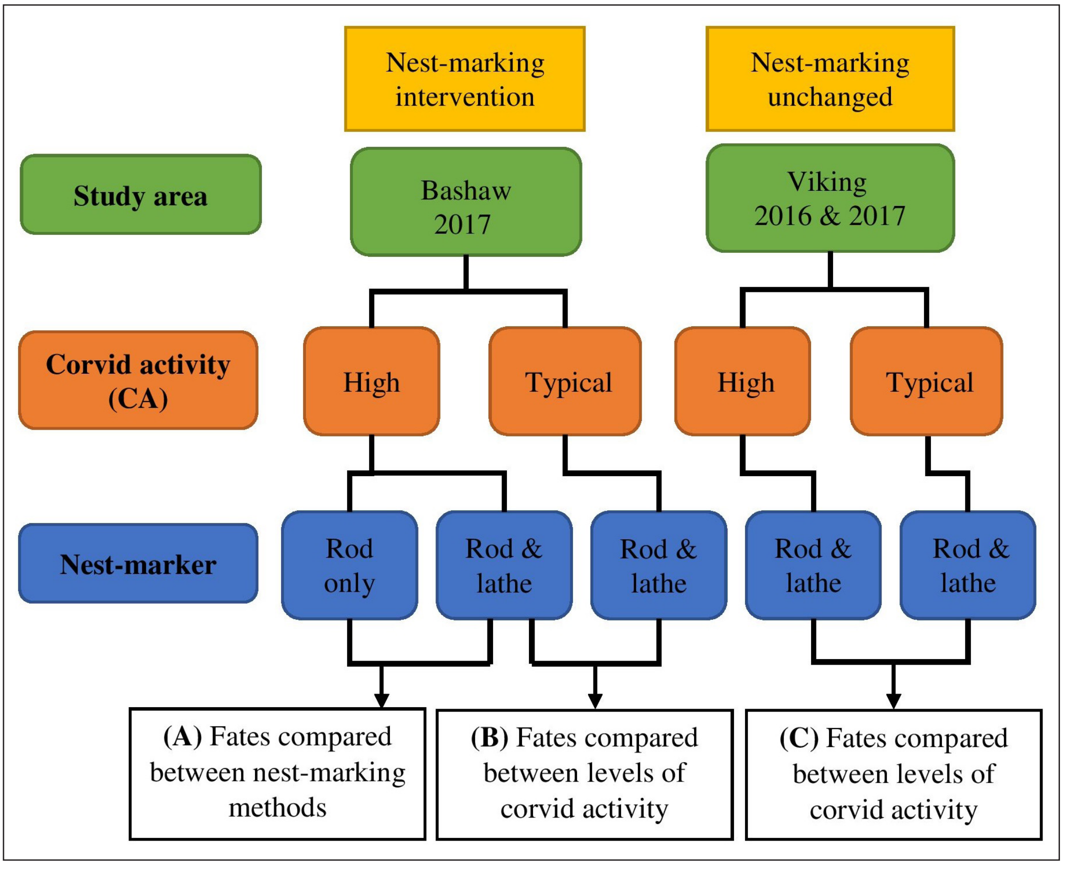

Figure 4. A description of the study design showing which combinations of study areas, observed corvid activity levels, and nest-marking methods were compared in Alberta, Canada in 2017. The high-corvid activity (CA) area in the Bashaw study area consisted of a single quarter section (*n* = 1), and high-CA areas in the Viking study areas consisted of 8 non-contiguous quarter sections (*n* = 8).

was made to nest-marking methods. The intervention consisted of marking nests with a rod only (i.e., no lathe). Thus, there were 2 high-CA areas, 1 area with a nest-marking intervention and 1 area without (Figure 4).

Within the high-CA area that had an intervention, we compared fates of nests marked with a rod-lathe combination to those marked with a rod only using a Fisher's exact test ($\alpha = 0.05$; A in Figure 4). As a control, we compared fates between lathe-and-rod-marked nests monitored in high-CA areas to those in typical-CA areas (B in Figure 4) using a Fisher's exact test ($\alpha = 0.05$). Zero counts were adjusted by adding 1 to all categories prior to testing.

In the study area where no nest-marking intervention was done, we made 2 comparisons between high-CA and typical-CA areas using chi-square tests of independence ($\alpha = 0.05$; C in Figure 4). First, we compared fates of nests monitored in high-CA and typical-CA areas. Second, we compared the number of depredated nests that were completely devoid of eggshells (versus eggshells remaining) between high-CA and typical-CA areas. Complete absence of eggshells is characteristic of predation by American crows (Sargeant et al. 1998) and common ravens (Lockyer et al. 2013) because both species commonly transport whole eggs from nests (Montevecchi 1976). However, absence of eggshells also can indicate predation by mammalian predators (Sargeant et al. 1998, Coates et al. 2008), but we considered this method sufficient because mammalian predators are olfactory oriented (Conover 2007) and would not be expected to benefit from visual markers. Field observations of duck eggshells found at the base of trees, apparently dropped by corvids, indicated that corvids were transporting whole eggs from duck nests at our study sites. We therefore assigned corvid predation to empty depredated nests and assumed corvids were not responsible for depredations where eggshells remained. Yates's continuity correction (Yates 1934) was applied to both chi-square tests. Finally, we compared the proportion of nests that failed during the first observation interval between high-CA and typical-CA areas to look at predation rates in the days immediately following initial nest marking. We note that apparent nest success could be confounded with nest density. We expected more nests to fail in the first interval in high-CA areas because the activities of nest searching and nest marker installation appeared to attract the interest of corvids in high-CA areas and not in typical-CA areas.

In the Bashaw study area (nest-marking intervention), typical-CA areas were non-contiguous quarter sections (single or partially adjoined groups of quarter sections dispersed among land parcels not within the study) that had no predator removals in 2017 and did have predator removals in 2016 (n = 9). In the Viking study area (no nest-marking intervention), typical-CA areas included all quarter sections with predator removal in 2016 (spatially paired) and 2017 (temporally paired) and all those with no predator removal in 2016 (paired predator treatment; n = 23). Confounding variables in our study design include predator removal and the amount of time corvids were exposed to our nest markers over the whole of our study, both of which could affect learning (Cornell et al. 2012) and nest predation. Predator removal showed no effect on nest survival at either study site (Blythe and Boyce 2020).

All sites are comparable based on a standardized nest-check interval, and we rely on counts of nest fates (hatched or depredated) rather than nest survival rates to more directly evaluate nest-marking methods. Observer effects could not be modeled using a time-varying covariate due to insufficient variation in nest-check intervals (Rotella et al. 2000, 2004); the majority of our nests were checked at 7-day intervals. All analyses were conducted in R (R Core Development Team 2021). Nest monitoring was approved by University of Alberta's Animal Care and Use Committee (AUP00001473) and permitted by Alberta Environment and Parks (Research Permit #57638 and Collection Licence #57639).

Results

In the high-CA area with a nest-marking intervention (A in Figure 4), 33 nests were monitored; 21 nests were marked with a rod and lathe, and 12 nests were marked with a rod only. Three nests were excluded from analysis because they were abandoned, and 2 nests were excluded because they were monitored with trail cameras. We used 28 nests in the analysis; all 19 marked with a rod and lathe were depredated, while of those marked with a rod only, 4 were depredated and 5 hatched. Nests marked with a lathe and rod were more likely to be depredated than those marked with a rod only (P = 0.003, odds ratio = 21.03, 95% CI of odds ratio = 1.94–1147.20, n = 28).

In the control for the nest-marking intervention, of the nests marked with a lathe and rod in the typical-CA areas, 60 were depredated and 43 hatched. Comparison of lathe-and-rod-marked nests in high-CA and typical-CA areas (B in Figure 4), indicated that nests in high-CA areas were significantly more likely to be depredated than those in typical-CA areas (P < 0.001, odds ratio = 14.23, 95% CI of odds ratio = 2.16–609.53, n = 122).

In the study area where no nest-marking intervention occurred (C in Figure 4), nests in high-CA areas were more likely to be depredated than those in typical-CA areas (χ^2_1 = 27.32, P < 0.001, n = 394). There were significantly more depredated nests void of eggshells in high-CA areas relative to typical-CA areas (χ^2_1= 72.44, P < 0.001, n = 210) for nests with descriptions of nest predation evidence. This result suggests a link between high-CA areas (where investigators suspected search images had formed) and corvid predation of nests marked and visited by researchers.

Depredated nests were much more likely to fail in the first nest-monitoring interval (following initial marking) in high-CA areas compared to typical-CA areas. The proportion of nests that failed to survive their first observation interval was more than double within high-CA areas (79%) relative to the mean proportion within typical-CA areas (35%). For all nests, the median Robel measurement of visual obstruction was 47 cm (interquartile range = 37–62 cm; Robel et al. 1970).

Discussion

Based on our field observations and anecdotes from previous studies (J. Brice, Delta Waterfowl, personal communication), we suspected that low nest survival in some sites was resulting from corvids forming search images for nests marked with lathes. We provide evidence that the conventional method of marking ground nests with a wooden lathe can increase predation by corvids in some situations. We recommend that researchers evaluate alternative methods of marking ground nests; in our study, nests marked with an inconspicuous flexible rod at the nest bowl were more likely to hatch than those marked with a lathe and rod. Placing lathes at variable distances and directions appears to have no effect on nest survival (Picozzi 1975, Blythe and Boyce 2020), but removal of lathes appeared to reduce nest mortality.

Recognition of both the lathes used to mark nests and patterns in investigator activity could have been acquired by individual crows and ravens and shared through social learning (Cornell et al. 2012), facilitating artificially high nest predation rates. Our study design involved sites that were geographically distanced, and predator removal sites were not intermixed with control sites (Figure 3). Thus, we would expect different territorial corvid groups at different sites and for groups to have had different exposures to our removal efforts. Individual social groups might have responded to nest markers and researchers differently (Weidinger 2008) or might not have acquired recognition of marked nests or interacted with conspecifics that had acquired recognition (Cornell et al. 2012).

Alternatively, corvids might not have formed search images by recognizing lathes but used lathes as perches from which they observed the activity of nesting hens. In our study, corvids were occasionally observed perching on lathes, and avian excrement commonly was found on lathes. In a grassland environment, providing perches for avian nest predators in the form of nest markers might increase nest predation. A potential test of this nest-markers-as-perches hypothesis could involve altering lathes after installing them (e.g., bird spikes, because a sharpened tip might flatten when hammered in).

To test if greater observed corvid activity resulted in greater rates of corvid-caused depredation, we relied on evidence left at depredated nests. Inference of predator species from nest predation evidence is largely precluded by intraspecific variation and interspecific overlap in nest predation patterns, as well as the occurrence of multiple predation events (Larivière and Messier 1997, Larivière 1999). We categorized depredated nests by presence or absence of eggshells, the latter being indicative of crow or raven predation (Montevecchi 1976, Lockyer et al. 2013) but also characteristic of nest predation by other species (Sargeant et al. 1998, Coates et al. 2008). In addition to corvids, higher levels of depredated nests lacking shell fragments could have resulted from an increase in predation by red foxes, coyotes, Franklin's ground squirrels, raccoons, weasels, gulls, mink, and badgers (Sargeant et al. 1998, Larivière 1999, Coates et al. 2008). However, of these species, only corvids and coyotes were effectively removed in our experimental treatments (Blythe and Boyce 2020); thus, we would expect to see a similar pattern of predation between high-CA and typical-CA areas if different species were involved. In other words, a non-corvid predator species leaving no eggshells would have been expected to be equally active in both high-CA and typical-CA areas. Additionally, mammalian carnivores are primarily olfactory oriented whereas avian predators, including corvids, are visually oriented (Conover 2007). Because olfactory cues from human visits would have been at every monitored nest, the difference in foraging strategies between mammalian and avian predators supports the argument that higher nest mortality resulted from corvid predation. High rates of nest failure after initial marking and significantly more predation events consistent with corvid predation corroborate field observations of crows and ravens showing interest in investigators and targeting marked nests.

Our study design suffers from a lack of replication of nest-marking methods and potential confounding of nest fates with nest season progression and other confounding variables that were not controlled in our analysis. The primary focus of our study was the effect of predator removal on duck nest survival, and we only incorporated an evaluation of the effects of nest-marking when spurred by field observations. We did not investigate differences in apparent nest success in relation to corvid density. The intent of this research note is to serve as a call for studies designed to rigorously evaluate the effects of common nest-marking methods.

To evaluate and potentially account for effects of nest-marking on nest predation, other studies should incorporate an experimental test into field studies (Rollinson and Brooks 2007). Research on nests where crows, ravens, and other corvids are present should include designs to minimize the potential for recognition of nest markers. Density of simultaneously active nests should be considered because, as described by the potential-prey-site hypothesis (Martin and Roper 1988, Chalfoun and Martin 2009), nest density and therefore density of nest markers might positively influence the formation of search images. Marking nests with a wooden lathe at a 20-m distance in variable directions did not appear to prevent search-image formation by corvids (Picozzi 1975).

Investigator activity also can provide cues to nest predators, resulting in subsequent discovery of nests (Weidinger 2008). Observations by corvids of field investigators were suspected in our study to be leading to greater interest in nest markers and nests. Where interest in researchers by corvids is suspected to contribute the predation of monitored nests, sporadic hazing might be an effective deterrent. Anecdotally, we observed that corvids appeared to be less interested in researcher activities at locations where predator removal (including corvid removal) through shooting and trapping was occurring. We removed 186 ravens and 169 crows during 2 years of nest searching, and no high-CA areas were located where removal was actively occurring, although deterrence and removals are confounding.

Marking a nest with a rod alone can increase scent and disturbance of vegetation created by investigators when relocating nests because the reduced visibility requires increased search effort (Galligan et al. 2003). Time spent at the nest also increases with search time; visit duration is often limited by Animal Care protocols, and field efficiency results in higher sample sizes. Additionally, the risk of damaging eggs by inadvertently stepping on or running over nests increases with less-visible marking (Galligan et al. 2003). The use of Global Positioning Systems (GPS) and increased caution by investigators can mitigate but not eliminate these risks, especially for ground nests with high visual concealment. Furthermore, a GPS could not be watched while chain dragging because the nest searcher must be watching for flushing hens. Both visual marking and reliance on GPS have downsides, providing more reason to explore drone and thermal imaging technology for ground nest research (Galligan et al. 2003). However, current drone technology comes with its own suite of challenges, including high rates of false positive nest detections (Stander et al. 2021). Alternatively, study plots could be gridded using permanent markers as described in Martin and Geupel (1993) and nest locations plotted in relation to the permanent markers.

Management implications

Other studies using less conspicuous marking methods such as ours also have struggled to address investigator-induced predation. Studies of ground nests are built on a well-established body of literature, and our study is but one of many that employed the same time-honored field methods. However, our work demonstrates the risks associated with complacency in the failure to critically evaluate common methods.

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