



Effects of Military Activity on Breeding Birds

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ABSTRACT United States military bases provide habitat for a diverse suite of wildlife species despite intense anthropogenic disturbance inherent in training activities. Little research has examined how military activity affects wildlife reproduction. We compared parental investment, reproductive success, offspring and adult quality, and stress hormone concentrations of northern cardinals (*Cardinalis cardinalis*) breeding in areas that differed 10-fold in levels of on-ground military activity. We found no evidence of direct impacts of military activity on cardinals, nor did the reproductive success of several other passerine species appear to be affected. However, we observed American crows (*Corvus brachyrhynchos*) much less frequently in areas of high military activity, and cardinals nesting in those areas were less responsive to crow models. The apparent displacement of this nest predator suggests that military activity could indirectly benefit some wildlife. Although these results are promising for the conservation of birds that depend on military bases for breeding habitat, further assessment of direct and indirect effects of military training on a wider array of species is required before concluding that such activity is benign. © 2012 The Wildlife Society.

KEY WORDS American crow, anthropogenic disturbance, birds, military, northern cardinal, reproduction, Texas.

Many military installations support diverse wildlife populations by protecting large areas of otherwise scarce habitat (Tazik and Martin 2002, Boice 2006). Given that anthropogenic disturbance can adversely affect the physiology (e.g., Maxwell 1993, Fowler 1999, Van Meter et al. 2009), behavior (e.g., Gutzwiller et al. 1994, Stone et al. 2009), and breeding success (e.g., Boyle and Samson 1985) of wildlife, and that intense human activity is a regular feature of military installations, the conservation value of these installations may be compromised if the preservation of rare habitat does not compensate for disturbance caused by training activities. Although a better understanding of how military training activities affect animal reproduction might help to improve the conservation value of these lands, few peer-reviewed studies have quantified the impact of military activity on wildlife reproduction (Gutzwiller and Hayden 1997, Hayden 2006).

To address this knowledge gap we investigated effects of on-ground military activity on parental investment, reproductive success, offspring and adult quality, and physiology of breeding northern cardinals (*Cardinalis cardinalis*) and on

the nesting success of 6 other passerines. Birds are a good model taxa for understanding military effects because they are often among the most represented threatened and endangered taxa on military installations (Tazik and Martin 2002).

Previous studies have found that birds decrease offspring provisioning in response to anthropogenic disturbance (Fernandez and Azkona 1993, Steidl and Anthony 2000). Therefore, we predicted that cardinals exposed to more military training would decrease parental investment; specifically, nest defense and offspring provisioning. We characterized nest defense using the distance that incubating females flushed in response to an approaching human and the response of parents to a simulated nest predator. We predicted that if disturbance causes parents to decrease their level of investment, birds nesting in areas with high military activity would flush sooner and defend their nests less vigorously than undisturbed birds (Montgomerie and Weatherhead 1988, Guinness et al. 2001). We documented responses to both a person and a model crow to determine whether any behavioral differences were limited to human encounters or whether they may represent a more generalized response to all perceived threats.

Reduced nest defense in areas with high levels of military activity would potentially increase the predation risk for those nests, because nest defense is known to deter nest predation (e.g., Greig-Smith 1980, Weatherhead 1990).

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We therefore predicted that nests in high activity areas would have lower daily nest survival and decreased fledging success. Additionally, nestlings from these nests should grow more slowly if military disturbance leads to decreased offspring provisioning.

A decrease in the number and quality of offspring produced in areas with military activity would effectively reduce the quality of that habitat because birds are known to use variation in productivity to assess the future potential of a given location (Hoover 2003). If cardinals perceive areas with ongoing military activity as lower quality habitat, then dominant individuals should establish territories elsewhere, forcing lower quality individuals to settle in high activity areas. Therefore, we predicted that relative to birds in habitat with low activity, birds nesting in high activity areas should be smaller (Burton and Evans 2001), initiate nests later (Perrins 1970), and lay smaller clutches (Lack 1968).

At a proximate level, the adjustment of parental investment in response to military activity could arise through changes in corticosterone, the primary avian glucocorticoid, because corticosterone concentrations are often altered in response to exposure to stressful anthropogenic disturbance (e.g., Wasser et al. 1997) and has been shown to influence reproductive behaviors in birds (Wingfield et al. 1998, Wingfield and Sapolsky 2003). Activity by humans on foot or in vehicles, and detonations associated with military training are likely similarly stressful. Traditionally, increased exposure to acute human disturbance is expected to elevate baseline corticosterone levels (e.g., Wasser et al. 1997). Recent studies have shown, however, that repeated, long-term, unpredictable exposure to stressful stimuli (i.e., chronic stress) may reduce baseline (e.g., Homan et al. 2003, Rich and Romero 2005, Cyr and Romero 2007) and stress-induced corticosterone concentrations (e.g., Romero and Wikelski 2002, Homan et al. 2003, Rich and Romero 2005). We therefore predicted that cardinals nesting in areas with repeated exposure to military activity would have suppressed baseline and stress-induced corticosterone concentrations.

STUDY AREA

We conducted this study in 2007 and 2008 at Fort Hood, in central Texas (31.2°N, 97.8°W). Using our prior experience at Fort Hood and recommendations of personnel familiar with training locations, we selected 2 study sites prior to the 2007 breeding season, one in an area with relatively high military activity (hereafter high activity) and one in an area with relatively low military activity. We defined military activity as training on foot, in wheeled and tracked vehicles, or at occupied encampments. In 2008, we established 3 additional sites with a history of high activity and 2 more sites with low activity. We retained the 2007 low activity site, but could not use the high activity site from 2007 because land managers had substantially altered the habitat. We selected sites with similar plant structure and species composition for both levels of activity, with habitats ranging from oak-juniper (*Quercus* spp. and *Juniperus ashei*) woodlands to oak savannahs. Study sites ranged in size from approximately 11 ha to 150 ha.

METHODS

Estimation of Site Differences

Throughout both field seasons, we recorded the number and type of every military activity observed while working on a site. Each individual military unit (personnel, vehicle, etc.) was counted only once per day, even if it was observed on multiple occasions.

Because we were using a crow model in our nest defense trials and differences in the presence of crows among study sites could potentially affect the response of cardinals to nest-directed threats by crows (Fontaine and Martin 2006), we used the number of crows counted on each site in 2008 as an index of relative crow abundance. We recorded every crow seen or heard, while trying to avoid counting the same individual more than once per day by recording crows only in areas where no others had been detected that day. This estimate reflected both the abundance and activity of crows in the area, which cumulatively provide an index of their abundance based on the same cues available to nesting passerines.

We spent 56,890 minutes on high activity sites and 75,070 minutes on low activity sites. Therefore, we report military activity and crows detected per hour when comparing high and low activity sites.

Nest Monitoring

We searched for nests from dawn until mid-afternoon between mid-March and late-August of both years, but sites were large enough that we did not find every cardinal nest. We also located and monitored nests of other open-cup nesting passerines in 2008 to determine if variation seen in productivity was consistent among species. These species included Bell's vireo (*Vireo bellii*), black-capped vireo (*V. atricapilla*), white-eyed vireo (*V. griseus*), blue-gray gnatcatcher (*Poliophtila caerulea*), northern mockingbird (*Mimus polyglottos*), and painted bunting (*Passerina ciris*). We checked nests approximately every other day, with more frequent visits as nestlings approached fledging to ensure accurate determination of nest fates. To determine clutch initiation dates for nests found after the onset of incubation, we backdated from the date of hatching (Halkin and Linville 1999). If such nests were depredated before hatching, we assumed nests were halfway through incubation at the middle of the period they were known to be active. Because the earliest known second nesting attempt in either year was started on 6 May, we considered only nests initiated prior to 1 May to be first attempts.

Nest Defense

We estimated behavioral responses to simulated nest threats up to 3 times during a nesting attempt: incubation, early nestling (1- to 5-day old), and late nestling (6- to 10-day old). A trial consisted of exposing the focal cardinal nest sequentially to a human observer and to a plastic American crow (*Corvus brachyrhynchos*) decoy placed 1–2 m from the nest, both of which cardinals respond to as nest threats. To prevent cardinals from responding to the researcher during placement of the crow, the observer set it up quickly when

parents were not nearby. We randomly determined the order of presentation of the threats and had a 2-hour break between presentations, with the first threat presented 2–2.5 hours after sunrise. We did not conduct nest defense trials if it was raining. We recorded the latency (time elapsed) to detection of the threat by either parent, total number of vocalizations, duration of response by each parent, and closest approach to the threat by each parent. We scored each behavior on a scale from 1 to 5, with greater values representing a stronger response (Table 1). We then added the scores of these 6 variables to form a composite nest defense score, ranging from 0 (no defense) to 30 (maximum defense). By recording multiple behavioral traits, we were able to generate a more representative estimate of nest defense (Gunness and Weatherhead 2002). After 5 minutes, the observer removed the threat and left the area. We made observations during exposure to the crow decoy from a small, camouflaged blind approximately 15–25 m from the nest, which was set up the previous day.

We also recorded flushing distances of incubating female cardinals (males do not incubate) during nest checks as an additional measure of nest defense. The observer approached each nest at a steady walking pace with arms at their sides to avoid inconsistencies in the perceived threat by the birds and recorded their distance from the nest when the female flushed.

Nestling Provisioning

To test the prediction that birds on high activity sites would reduce nestling provisioning, we monitored nestling provisioning from a blind using a spotting scope (20–60×

Table 1. Scores for each variable measured in northern cardinal active nest defense trials in 2007 and 2008 at Fort Hood, Texas. We added the scores of these variables together to produce a composite nest defense score, ranging from 0 to 30.

Variable	Value	Score
Latency to detection ^a	0–10 min	5
	10.01–20 min	4
	20.01–30 min	3
	30.01–40 min	2
	40.01–60 min	1
	>60 min	0
Total vocalizations ^a	401+	5
	301–400	4
	201–300	3
	101–200	2
	1–100	1
Response duration ^b	0	0
	241–300 s	5
	181–240 s	4
	121–180 s	3
	61–120 s	2
	1–60 s	1
Closest approach ^b	0 s	0
	0–3.9 m	5
	4–7.9 m	4
	8–11.9 m	3
	12–15.9 m	2
	16+ m	1
	Never approached	0

^a Recorded for the breeding pair.

^b Recorded independently for male and female parents.

magnification). We made observations in the early nestling (1- to 5-day old) and late nestling (6- to 10-day old) stages during the second hour of the 2-hour interval between successive nest defense trials to ensure that birds had resumed normal activity following the first nest threat presentation. We did not conduct observations if it was raining. In addition to recording the number of feeding visits to the nest by each parent, we also estimated food load size. We gave prey items a value of 1 if they were completely contained within the parent's bill, 2 if they protruded slightly from the bill, and 3 if they protruded obviously from both sides of the bill (Lessells et al. 1998, Shiao et al. 2009). In 2008, we weighed cardinal nestlings when they were approximately 6-day old to assess the relationship between provisioning effort and nestling mass.

Blood Collection and Estimation of Stress Hormone Concentrations

We captured male birds in mist-nets by attracting them with playbacks of conspecific vocalizations. We excluded females from analyses of hormones and body size because they are not easily decoyed into nets. We took blood samples from each bird by pricking the brachial vein with a hypodermic needle and collecting up to 60 μ l of emergent blood in heparinized microhematocrit tubes. We took the first blood sample within 3 minutes of capture to determine baseline corticosterone concentrations (Romero and Romero 2002). We then placed birds into an opaque cloth bag for 30 minutes, after which we took another blood sample to measure acute stress-induced corticosterone levels (Wingfield 1994). We stopped blood flow by applying pressure with a cotton ball. We stored blood samples on ice in the field. Prior to release, we measured each bird's tarsus length and attached a United States Fish and Wildlife Service aluminum leg band and a unique combination of plastic color leg bands.

Within 24 hours of collection, we spun microhematocrit tubes at 1,545g for 10 minutes in a Zipocrit centrifuge (LW Scientific, Lawrenceville, GA) and then extracted plasma using a 50 μ l Hamilton syringe. We then transferred plasma samples to 0.5 ml Eppendorf tubes (Eppendorf, Hamburg, Germany) and stored them at -18° C until transfer to Tufts University. We measured corticosterone concentrations in a single radioimmunoassay with intra-assay variability of 4.2% after extraction with dichloromethane as described by Wingfield et al. (1992). We excluded from analyses 2 samples with values greater than 3 standard deviations from the mean. All methods were approved by the University of Illinois Institutional Animal Care and Use Committee (Protocol #08010).

Statistical Methods

We estimated daily survival rates of nests using logistic-exposure (Shaffer 2004), modeling cardinal data separately and pooling all other passerines. We did not include nest stage, date, and year as covariate factors in the model because our samples were balanced across military activity levels. We assessed differences in estimates of nest defense (active nest defense and flushing distance), nestling provisioning (feeding rate per nestling and mean food load size), fledging

success (number of fledglings per egg), and clutch size between birds occupying high and low activity sites using linear mixed models with breeding pairs as the random factor and level of military activity and nest threat as fixed factors. We used the Bonferroni correction for estimates of active nest defense when comparing nest threats for a given activity level and when comparing activity levels for a given nest threat. We included Julian date, time after sunrise, age of young, and number of young as covariates in the analysis of nest defense (Montgomerie and Weatherhead 1988) and nestling provisioning, but included only Julian date, number of eggs, and age of eggs as covariates for flushing distance (Albrecht and Klvana 2004, Osiejuk and Kuczynski 2007). Although multiple studies have shown no impact of previous exposure on passerine nest defense (e.g., Weatherhead 1989), there has been some debate over the issue of non-independence among trials (Knight and Temple 1986, Siderius 1993). Therefore, we included the number of times parents had been exposed to a researcher prior to the trial as a covariate of nest defense, including both monitoring visits and previous nest defense trials. We determined differences in baseline and stress-induced corticosterone concentrations using a similar linear mixed model with Julian date as a covariate (Romero 2002) and employed Bonferroni corrections when comparing activity levels for either baseline or stress-induced samples. We evaluated differences in average nestling mass, date of initiation of first clutch, and adult tarsus length between birds from high and low activity sites using an analysis of variance (ANOVA) with military activity level as a fixed factor. We included day of year, number of nestlings, and age of nestlings as covariates for analyses of average nestling mass. We conducted all analyses using the program NCSS (J. L. Hintze, Kaysville, UT), except daily survival rates which were analyzed using SAS 9.1 (SAS Institute, Cary, NC).

RESULTS

Site Differences

On sites designated as high activity we observed military personnel, small vehicles, large vehicles, and tracked vehicles >10 times more often than on low activity sites (mean detections/hr: personnel high = 0.86, personnel low = 0.07; small vehicles high = 0.63, small vehicles low = 0.05; large vehicles high = 0.12, large vehicles low = 0.00; tracked vehicles high = 0.12, tracked vehicles low = 0.01). Military activity on high activity sites was unpredictable in type, duration, and exact location and was episodic (detected on 51% of site visits), with high levels of sustained presence separated by brief lulls in activity. When troops were present, they often caused considerable noise by firing guns, artillery, and explosive ordinances, in addition to the more constant sounds of conversation and vehicle operation. In contrast, we never observed encampments or long-term occupation by troops on low activity sites.

We detected 474 American crows on low activity sites but only 66 on the high activity sites (mean detections/hr: high = 0.07, low = 0.38). Although we did not formally

estimate northern cardinal densities, they appeared similar across sites.

Parental Investment

We conducted 251 nest defense trials (128 high activity, 123 low activity) from 63 territories (32 high activity, 31 low activity), with these trials divided between American crow and human nest threats, and recorded 172 flush distances (100 high activity, 72 low activity) from 61 territories (32 high activity, 29 low activity). Cardinals at all sites followed the expected trend of increasing nest defense as the age of the nest increased ($F_{1,162.1} = 34.89$, $P < 0.001$; Fig. 1). When analyzed independent of type of threat, adult cardinals defended their nests 8% less aggressively on sites with high military activity ($F_{1,50.4} = 5.11$, $P = 0.03$; Fig. 1). When nest threats were separated, however, cardinals from low activity sites responded 11% more strongly to the crow decoy than did birds from high activity sites ($F_{1,140} = 5.51$, $P = 0.04$; Fig. 2) but we found no difference in their responses to the human threat ($F_{1,143.6} = 0.99$, $P = 0.64$; Fig. 2). Likewise, birds responded similarly to crow and human threats on high activity sites ($F_{1,198.6} = 2.08$, $P = 0.30$; Fig. 2) but were 13% more defensive toward the crow on low activity sites ($F_{1,196.8} = 7.84$, $P = 0.01$; Fig. 2). Incubating females did not flush from an approaching human at different distances on high and low activity sites ($F_{1,58.2} = 0.89$, $P = 0.35$; Fig. 3).

We also recorded provisioning at 79 nests (41 high activity, 38 low activity) from 47 territories (24 high activity, 23 low activity). Cardinals provisioned nestlings similarly on high and low activity sites as measured by feeding rate per nestling ($F_{1,34.9} < 0.01$, $P > 0.99$; Fig. 4) and mean food load size ($F_{1,30.3} = 0.93$, $P = 0.34$; Fig. 4).

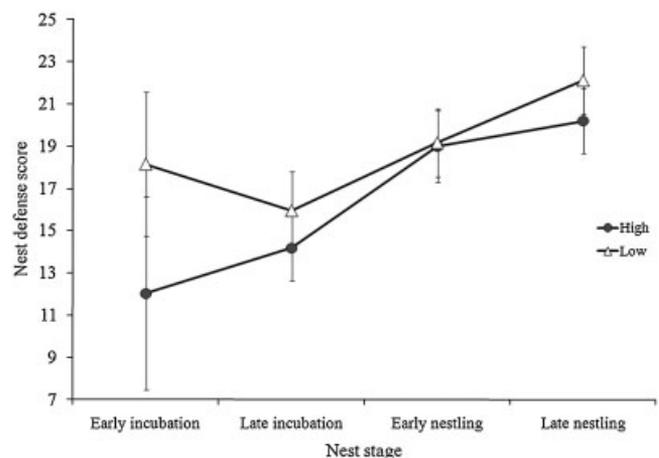


Figure 1. Mean nest defense scores ($\pm 95\%$ CI) of adult northern cardinals with young in multiple nest stages on high and low military activity sites between 2007 and 2008 at Fort Hood, Texas. Nest defense scores are a composite of latency to detection, number of vocalizations, duration of response, and closest approach. Nest stages are early incubation (1–8 days), late incubation (9–16 days), early nestling (17–21 days), and late nestling (22–26 days). This figure includes 250 nest defense trials (127 high activity, 123 low activity) from 62 territories (31 high activity, 31 low activity), with these trials divided between American crow and human nest threats.

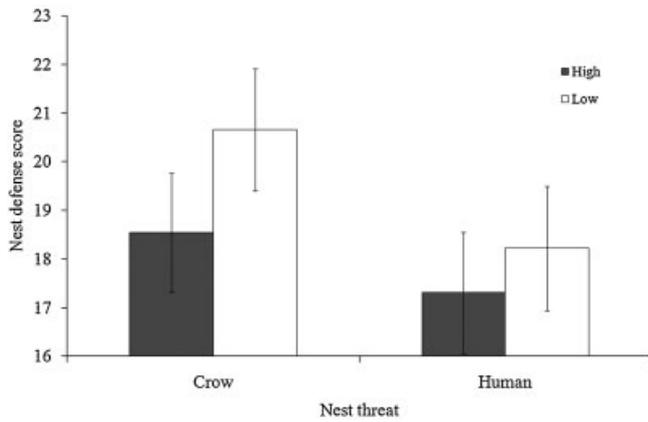


Figure 2. Mean nest defense scores ($\pm 95\%$ CI) of adult northern cardinals to each threat type between sites with high and low military activity between 2007 and 2008 at Fort Hood, Texas. Nest defense scores are a composite of latency to detection, number of vocalizations, duration of response, and closest approach. We include 251 nest defense trials (128 high activity, 123 low activity), divided approximately equally between American crow and human nest threats, from 63 territories (32 high activity, 31 low activity).

Productivity

We found 123 cardinal nests (62 high activity, 61 low activity) and 28 nests of other passerines (14 high activity, 14 low activity). Calculations of daily survival rates were based on 768 observation days for cardinals and 147 observation days for other passerines. Overall nest success was 40% and 39% for cardinals and other passerines, respectively. Daily nest survival rates and fledging success of cardinals and other passerines were similar between activity levels (Table 2), as were the causes of nest failure (cardinal high activity: 36/38 [95%] predation, 1/38 [3%] abandonment, 1/38 [3%] weather; cardinal low activity: 29/32 [91%] predation, 3/32 [9%] abandonment; other passerine high activity: 9/9 predation; other passerine low activity: 7/8 predation, 1/8 abandonment). Average nestling mass was also similar between activity levels (high activity: $\bar{x} = 17.7$ g,

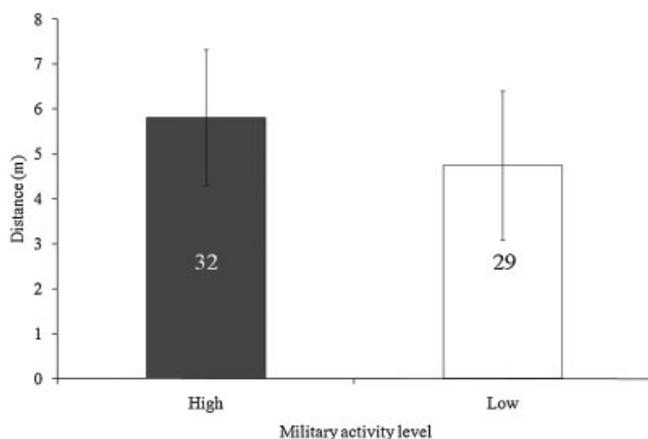


Figure 3. Mean flushing distance ($\pm 95\%$ CI) of incubating female northern cardinals inhabiting high and low military activity sites between 2007 and 2008 at Fort Hood, Texas. We recorded 172 distances, with 100 high activity and 72 low activity. Values within bars represent the number of females included on each site.

95% CI = 16.5–19.0, $n = 15$; low activity: $\bar{x} = 17.5$ g, 95% CI = 16.2–18.8, $n = 14$, $F_{1,24} = 0.08$, $P = 0.78$).

Adult Quality

Contrary to our prediction, adult males were not larger in areas of low activity (mean tarsus length: high activity $\bar{x} = 28.03$ mm, 95% CI = 27.61–28.46, $n = 16$; low activity $\bar{x} = 28.30$ mm, 95% CI = 27.83–28.77, $n = 13$, $F_{1,27} = 0.72$, $P = 0.40$). Similarly, birds occupying high activity sites did not initiate their first clutch later (Julian date: high activity $\bar{x} = 105.88$, 95% CI = 101.16–110.60, $n = 25$; low activity: $\bar{x} = 105.10$, 95% CI = 99.95–110.24, $n = 21$, $F_{1,44} = 0.05$, $P = 0.82$) or produce smaller clutches (high activity: $\bar{x} = 3.05$, 95% CI = 2.84–3.26, $n = 36$; low activity: $\bar{x} = 3.29$, 95% CI = 3.08–3.51, $n = 36$, $F_{1,72.8} = 2.54$, $P = 0.12$) than birds on low activity sites.

We collected hormone samples from 16 individuals on high activity sites (0 min: $n = 16$; 30 min: $n = 15$) and 14 individuals on low activity sites (0 min: $n = 12$; 30 min: $n = 12$). As expected, corticosterone concentrations for cardinals from both high and low activity sites increased significantly above baseline concentrations after 30 minutes of restraint ($F_{1,24.6} = 87.58$, $P < 0.001$; Fig. 5). Contrary to our prediction, however, we found no difference between either baseline ($F_{1,49.9} = 0.002$, $P > 0.99$) or stress-induced ($F_{1,49.9} = 1.43$, $P = 0.48$) corticosterone levels of cardinals from high and low activity sites (Fig. 5).

DISCUSSION

Despite frequent troop activity and associated noise from vehicles and gunfire on high activity sites, birds breeding nearby did not appear to be directly affected. We found no evidence that those birds decreased their offspring provisioning or nest defense toward human threats or were less successful at reproducing. Furthermore, the similarities in body size, clutch size, and nest initiation date suggest that the quality of cardinals did not differ between habitats with high and low activity levels, and the similarities in both baseline and stress-induced corticosterone levels suggest that military activity was not stressful to the birds.

The apparent lack of detrimental effects of military activity on breeding cardinals can be interpreted in 2 ways. Either cardinals are tolerant of high levels of disturbance, or alternatively, their tolerance threshold for disturbance is so low that cardinals on both high and low sites were equally disturbed. Some types of military training are detectable over wide areas (e.g., gunfire), so even cardinals with little close contact with troops or vehicles still experienced some exposure to military activity. Nonetheless, we consider the low disturbance threshold explanation less likely than the high tolerance explanation because loud noises, such as gunfire, ordinance explosions, and helicopter travel were much more frequent and intense on sites designated high activity, which should have resulted in differences between treatments if these types of disturbance were affecting birds. Furthermore, cardinals on both types of sites exhibited normal patterns of parental behavior over the nesting period and the ability of cardinals to mount a large corticosterone

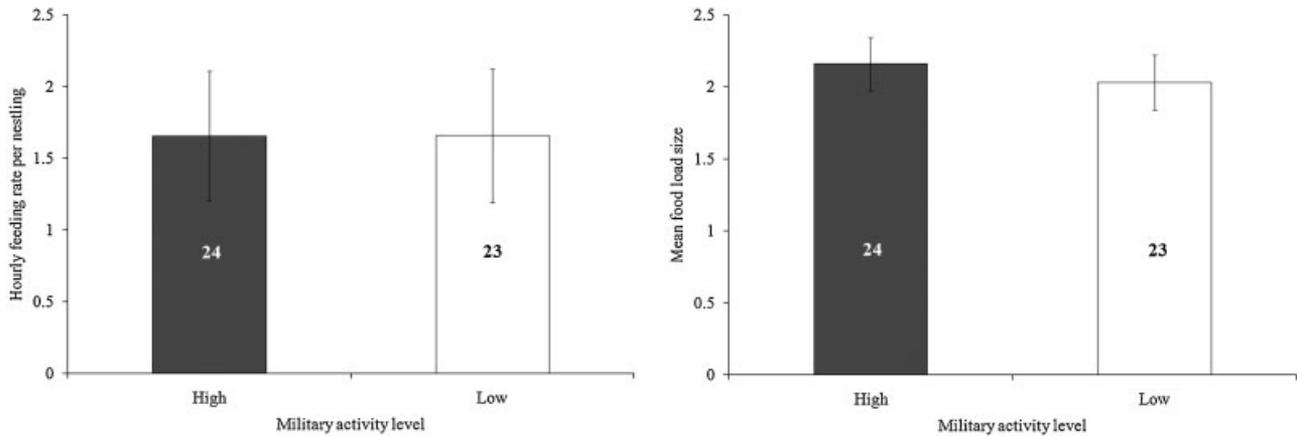


Figure 4. Mean feeding rate per nestling ($\pm 95\%$ CI) and food load size ($\pm 95\%$ CI) of adult northern cardinals on high and low military activity sites between 2007 and 2008 at Fort Hood, Texas. We included 79 observations of provisioning, 41 from high activity sites and 38 from low activity sites. Values within bars represent the number of territories included.

response to capture and restraint on both high and low activity sites was not consistent with them having prolonged exposure to acute stress (Homan et al. 2003, Rich and Romero 2005, Cyr and Romero 2007). Although it is possible that only birds on high activity sites developed such a tolerance through habituation to frequent and stressful military disturbance, this explanation seems unlikely considering that these birds did not exhibit a down-regulation of their hormonal stress response. As with any study, the possibility remains that our findings could be due to a lack of power or missing covariates. However, our relatively large sample sizes and comparable means suggest no biologically meaningful difference between levels of military activity. Thus, we interpret our results as indicating that cardinals were not stressed or otherwise adversely affected by military activity.

Cardinals' breeding habitat includes suburban areas (Halkin and Linville 1999), indicating some degree of tolerance for human activity. Even so, we were surprised by the lack of response to military training and question whether other birds less adapted to human-influenced habitats are similarly tolerant of military training. Although we did not collect data on the breeding behavior of other species, nest success and productivity for other open-cup nesting passerines (including 7 nests of the endangered black-capped vireo) indicated that, like cardinals, these birds were unaffected by military training. Moreover, previous studies conducted at Fort Hood showed that military and other human activity

did not cause major behavioral (Hayden 2006), hormonal (Hayden 2006, Butler et al. 2009), or energetic (Bisson et al. 2009) impacts on nesting black-capped and white-eyed vireos. The tentative conclusion from these results, therefore, is that limiting the intensity of military training during the breeding season is unlikely to enhance reproductive success of many songbird species. Managers should be cautious in lifting training restrictions, however, as suggested by the negative effects of such a removal on black-capped vireo offspring production (Hayden 2006).

Although the birds we studied appeared unaffected by military training, we did find evidence that habitat use and/or activity of the American crow, a predator of passerine nests, were affected by military activity. We detected American crows 5 times more often on low activity than on high activity sites. Knight et al. (1987) found that crows nesting in urban areas were less wary of people than crows nesting in rural habitat and attributed that difference to human persecution (i.e., hunting) of rural crows. Crows in our study likely reacted to troops carrying and firing weapons in a similar fashion. This suggests that species hunted by humans will be more adversely affected by human activity, including military training, than species that are not hunted (Boyle and Samson 1985).

The response of crows to anthropogenic disturbance provides a means through which nesting songbirds could be indirectly affected by military training. First, we found

Table 2. Daily nest survival rate and mean number of fledglings produced per egg for northern cardinals and other passerine species occupying sites with high and low levels of military activity at Fort Hood, Texas between 2007 and 2008. Calculations of daily survival rates are based on 123 total nests for cardinals (observation days = 768) and 28 total nests for other passerines (observation days = 147).

Species	Military activity	Daily survival rate		Number of fledglings per egg			
		Mean	95% CI	Mean (n^a)	95% CI	F	P
Northern cardinal	High	0.942	0.921–0.958	0.33 (51)	0.20–0.45	0.37	0.55
	Low	0.945	0.924–0.961	0.38 (51)	0.26–0.51		
Other passerines	High	0.944	0.896–0.971	0.35 (13)	0.02–0.67	0.49	0.49
	Low	0.944	0.892–0.972	0.50 (14)	0.19–0.81		

^a Values in parentheses indicate the number of territories included in repeated measures analyses.

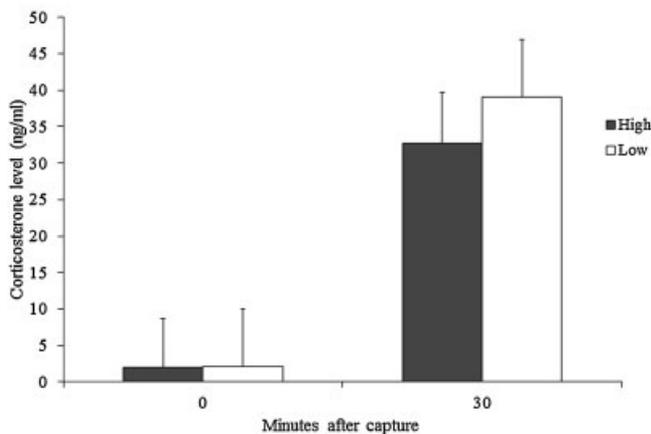


Figure 5. Mean corticosterone levels ($\pm 95\%$ CI) of male northern cardinals occupying high and low military activity sites in 2008 at Fort Hood, Texas. The 0-minute time includes samples collected within 3 minutes of capture and represents baseline levels, whereas the 30-minute time represents stress-induced levels. Samples were taken from 16 individuals on high activity sites (0 min: $n = 16$, 30 min: $n = 15$) and 14 individuals on low activity sites (0 min: $n = 12$, 30 min: $n = 12$).

stronger reactions to a crow decoy on low activity sites, where crows were more abundant. This behavioral change is consistent with breeding birds elevating their nest attentiveness in response to increased predator abundance (Fontaine and Martin 2006). We speculate that a comparable adjustment to human abundance was not observed because humans rarely pose a genuine threat to offspring. This critical distinction could lead cardinals to perceive nest-directed threats from a natural predator differently from nest-directed disturbance by humans. Differential perception of crow and human threats to nests has been suggested previously for black-capped vireos (Butler et al. 2009). Second, a decrease in the abundance and/or activity of crows or other predators in areas with high military training could actually confer an indirect benefit to nesting passerines. We found no difference in nest predation to support this idea, but the effect could have been obscured by predation from species less likely to avoid military activity, such as fire ants and snakes, which appear to be the primary predators of passerine nests in the area (Stake and Cimprich 2003, Stake et al. 2004). Our findings suggest that conservation biologists investigating effects of military or other disturbance on wildlife should be aware of the potential for indirect effects.

MANAGEMENT IMPLICATIONS

If training activity compromises the wildlife conservation value of habitat preserved on military installations, efforts to modify the timing or intensity of training might be warranted. Our findings that cardinals and several other species of passerines were unaffected by military activity during the breeding season suggest that steps to mitigate the effects of training may be unnecessary. However, we did not quantify direct effects of training activity that result when habitat is physically altered. Furthermore, until data are available for a broader array of birds and other wildlife, we cannot assume that all wildlife are similarly unaffected

by military activity. Our evidence that crows appear to avoid areas with military activity illustrates both that some species may be disturbed by military activity and that community-level indirect effects could result. As such, managers of military lands can be cautiously optimistic about the limited impact of training disturbance on wildlife, but should simultaneously promote the need for future research.

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