RESPONSES OF NESTING SANDHILL CRANES TO RESEARCH ACTIVITIES AND EFFECTS ON NEST SURVIVAL

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Abstract: We examined the response of nesting greater sandhill cranes (*Grus canadensis tabida*) to research-related activities at Grays Lake, Idaho, during 1997–2000. Data were collected on >500 crane nests from 53 fields that were exposed to variable levels of research activity, from fields subjected to only periodic searches for and monitoring of crane nests (crane-only fields) to fields subjected to periodic searches for and monitoring of all waterbird nests as well as breeding bird surveys, nocturnal amphibian surveys, and other research-related activities (multi-use fields). For each nest, we calculated the visit rate to the field during the period the nest was known to be active (hereafter field visit rate) as the number of observer visits to a field while the nest was known to be active divided by the number of exposure days of the nest. The median field visit rate for all years was 0.188 visits/day, which would equate to 5.6 visits over the course of a 30-day incubation period. Length of field visits for most activities averaged 93–155 min. Of known responses, most (83.7%) cranes were flushed, but actual frequency of flushing (considering unknown responses as not flushed) was likely ~30%. Frequency of flushing for known responses was highest during nest searches (89.4%) and nest checks (87.9%) and lower during bird surveys (68.1%) and other activities (54.3%). Half of cranes that were observed to flush did so when the investigator was between 20 and 80 m away (25 and 75% quartiles, respectively; median = 32.5 m). Median flushing distances tended to be greatest for nests located in very short vegetation, but the response differed between cranes nesting in multi-use fields and cranes nesting in crane-only fields. We found no relationship between flushing distance and number of field visits. We examined the effects of field visit rate and year on nest survival using logistic-exposure approach and Akaike's Information Criterion to evaluate support for 3 models. The model including field and year was most supported by the data; we found no support for field visit rate as an important variable explaining nest success.

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Collecting data on nesting waterbirds often involves some type of potential disturbance to nesting birds, whether direct (e.g., handling eggs) or indirect (e.g., walking near birds on nests). Disturbances can result in lower clutch size, hatching success, fledging success, or overall reproductive success (Ellison and Cleary 1978, Anderson and Keith 1980, Åhlund and Götmark 1989, Götmark 1992). Disturbances may also discourage birds from renesting or from initiating late nests (Ellison and Cleary 1978, Tremblay and Ellison 1979). Alternatively, individual birds may become tolerant of human intrusions after repeated exposure (Nisbet 2000). Many scientific investigators are aware of the potential impact of their activities and seek a balance between minimizing disturbance and collecting useful and timely data. That balance may be more difficult to achieve in studies that have multiple components, of which nesting is only one. Understanding the responses of nesting birds to various types of disturbances is important to ensuring unbiased data and to minimizing potential impacts on a nesting population.

Although many studies have evaluated the effects of human disturbances in Anseriformes, Charadriiformes, and Pelecaniformes (Götmark 1992), few studies have been conducted on Gruiiformes or wild cranes. Several studies report responses of foraging cranes to disturbances on staging, migration, or wintering areas (Herter 1982, Lewis and Slack 1992, Burger and Gochfield 2001). Most nesting studies provide only qualitative information on the tolerance of sandhill cranes (*Grus canadensis*) to human disturbances (Walkinshaw 1949, 1976, 1981; Valentine 1982; Stern et al. 1987). Quantitative assessments on the effects of human disturbances to nesting cranes are few (Dwyer and Tanner 1992, Nesbitt et al. 2005) and have been limited in sample size.

During 1997–2000, we conducted a study at Grays Lake National Wildlife Refuge (GLNWR) that included multiple research components and associated research-related activities. During the nesting season, we conducted periodic nest searches for and monitoring of nests of greater sandhill cranes (*G. c. tabida*) as part of a study to evaluate nesting ecology. On 12 fields, additional research activities included periodic searches and checks for nests of all waterbird species, breeding bird surveys, and nocturnal amphibian surveys. Crew size (number of people visiting fields at any one time) also was usually higher on these 12 fields. Varying levels of research activities on these fields over 4 years provided the opportunity to examine responses of cranes to research activities and to evaluate concerns about the impact of research activities on

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nesting cranes.

STUDY AREA

Grays Lake lies within the Caribou Range of the Rocky Mountains in southeast Idaho, at the western edge of the Greater Yellowstone Ecosystem. At the heart of the Grays Lake valley is a 5,260-ha shallow montane marsh which is vegetated primarily with bulrush (*Scirpus* spp.) and cattail (*Typha latifolia*) and bordered by temporarily and seasonally flooded meadows. Because of its high elevation (1,946 m), the valley is subject to prolonged winters and summers characterized by warm days and cool nights. Ranching (cattle, sheep, and hay production) is a predominant land use on private and state lands in the valley. Refuge land management included grazing, haying, idling, and fall burning.

Most of the interior deep marsh, as well as large areas of temporarily and seasonally flooded meadow, are contained within GLNWR. The central portion of this montane wetland is a large, contiguous area of permanently and semipermanently flooded wetland dominated by bulrush (*Schoenoplectus tabernaemontani*) and lesser amounts of cattail (8,854 ha; hereafter interior deep marsh). The habitats surrounding the interior deep marsh are a mosaic of seasonally (2,251 ha) and temporarily flooded (3,602 ha) habitats, variously dominated by sedges (*Carex and Eleocharis spp.*), Baltic rush (*Juncus balticus*), tufted hairgrass (*Deschampsia caespitosa*), Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), and mat muhly (*Muhlenbergia richardsonis*). Small stands of cattail-bulrush often occurred as patches within the seasonally flooded habitat. Most of these habitats are <1 m deep when flooded in spring. Heavy snowpack each winter results in little standing cover of residual vegetation in spring except in cattail stands. Crane nests are predominantly located in wet meadow, in Baltic rush (*Juncus balticus*), and on the outer edge of the bulrush-cattail marsh (Drewien 1973, Ball et al. 2003).

The 53 fields (as defined by fencing) used in this study ranged in size from 12 to 267 ha and were located along the lakeshore. Twelve fields (805 ha total), owned or managed by the U.S. Fish and Wildlife Service (USFWS), were subjected to experimentally applied management practices and multiple research activities (Austin et al. 2002); hence, we refer to them as "multi-use fields." These fields were distributed along the wet meadow-permanent marsh edge along the north, east, and southeast portions of the Grays Lake basin Other fields (20–24 each year; 41 total) were defined as "crane-only fields" because the only research activities were searches for and monitoring of crane nests. These fields, also distributed along the wet meadow-permanent marsh edge around the entire basin, were owned or managed by GLNWR, other federal and state agencies, and private landowners, and received various habitat management practices, most commonly grazing. Crane-only fields were 3–267 ha ($\bar{x}$ = 60 ha) and multi-use fields were 24–112 ha ($\bar{x}$ = 69 ha). Most fields encompassed a range of habitats, from cattail-bulrush stands to temporarily flooded wet meadow; some also included upland habitat. For a detailed description of the area, see Austin et al. (2002).

METHODS

Nest searching was conducted from late April to mid-June, 1997–2000. The 12 multi-use fields were searched every year; the numbers of crane-only fields searched varied from year to year (20–24 each year) due to variation in access to private lands and spring weather conditions. Crane nests were located by systematic searching on foot or by canoe, or by remote observation using binoculars or spotting scopes; some crane nests were found when cranes were flushed by all-terrain vehicles (ATVs). Field crews of 2–4 people conducted 4 systematic nest searches each year on the 12 multi-use fields and 1–2 people conducted 1–5 systematic searches on crane-only fields, depending on its size and location. Crane nests were visited at 10–20 day intervals until all nesting terminated, approximately 15 July. Some nest checks were made from a distance with binoculars or spotting scopes to reduce disturbance. ATVs were used for transportation to and from fields and, in multi-use fields, to locate nests of ground-nesting birds (including some cranes) with chain drags (Higgins et al. 1969). ATV activity was kept >30 m from known crane nests whenever possible, and observers approached crane nests on foot.

For each crane nest, we recorded information on nest status and nest fate following procedures established by Klett et al. (1986) and Northern Prairie Science Center (1995). We determined incubation stage by the flotation method (Westerskov 1950). Habitat type of each nest site was classified as: 0) upland (graminoids and forbs), 1) semi-wet meadow (intermittently-flooded habitat), 2) Baltic rush/spikerush (*Eleocharis* spp.) (hereafter referred to as Baltic rush), 3) robust sedge (*Carex utriculata* and other *Carex* spp.; hereafter referred to as sedge), 4) sedge/cattail/bulrush, 5) cattail/bulrush, 6) overwater, 7) willow (*Salix* spp.), or 8) other. During each direct nest visit, we categorized vegetation height based on the height of residual and new vegetation above the water (or soil surface if the nest was on dry ground) within a 3-m radius of the nest; categories were 0–10, 10–30, 30–60, 60–100, or >100 cm. Because cranes hatch asynchronously, we continued nest visits until the fates of both eggs were determined. A nest was considered successful if at least 1 egg hatched, as determined by the presence of chicks, tiny shell fragments, or detached membranes within 5 m of the nest platform (Rearden 1951; C. D. Littlefield, Muleshoe, TX, personal communication). Unless the exact initiation or hatch dates were known, nest

initiation dates and hatch dates were estimated from incubation stage (age of eggs) at the first nest visit, assuming a 30-day incubation period (Walkinshaw 1949).

For each field visit where at least 1 active (i.e., laying, incubation, or pipping stages) crane nest was present, observers recorded the following information: field number, date, observer, research activity (nest search, nest check, bird surveys, other), numbers of crane nests known to be active on that date in that field, and time of arrival to and departure from the field. All but the last parameter was recorded before entering the field, based on current nesting data, to ensure that observers were aware of every nest present and that all possible responses of cranes would be noted. "Other" research activities included nocturnal amphibian surveys, marking transects, or traveling through 1 field to reach another. Data were not recorded for field visits related to normal refuge maintenance activities such as fence repair. For each active nest present in the field, investigators recorded the nest number and nest status (unknown, egg-laying, incubation, destroyed, pipping, hatched, or lost) based on nest card data and any nest information collected during that visit. Observers also recorded 1) crane status upon observer entering or departing the field (unknown, on nest, ≤10 m of the nest, 11–50 m from nest, and >50 m from nest); 2) whether a crane associated (on or near) with a nest flushed during that visit; 3) time when the crane flushed; 4) distance from observer to crane if flushed (estimated nearest m); and 5) comments. "Flush" here is defined as a crane leaving a nest, whether by walking or flying.

Statistical Analysis

We used estimated nest initiation and termination dates to determine when each crane nest in a field was active (exposure days). These data were then used to ensure that there was a record for each active nest whenever a field was visited, even if a nest was not directly visited or for dates when we were unaware of its existence. Only those records when the nest was active (before hatch) were included. For each nest, we calculated the visit rate to the field during the period the nest was known to be active (hereafter field visit rate) as the number of visits to a field while the nest was known to be active divided by the number of exposure days of the nest. We examined the relationship between average flushing distance and number of field visits to which a nest was exposed using simple regression. We used a Student t-test for unequal variances to compare flushing distances between crane-only and multi-use fields.

The effects of field visit rate and year on nest survival were examined using the logistic-exposure method described by Shaffer (2004). For this analysis, field visit rate for each nest for each observation interval was calculated separately as the number of visits to the field during the interval divided by interval length. The logistic-exposure approach assumed survival and field visit rate were constant within a nest observation interval, but these rates were allowed to vary among intervals. Nest outcome for each observation interval was modeled as a binary variable (0 = failure, 1 = success) using PROC NLMIXED (SAS 2002). Field was included as a random effect in the model to acknowledge possible covariance among nests from the same field each year. Year was included in the model as a fixed effect. We fit 3 models: 1) field and year; 2) field, year, and field visit rate; and 3) field, year, field visit rate, and the interaction between year and field visit rate. We did not include incubation stage of the nest in the models because of inconsistencies in determining incubation stages among visits. We used Akaike's Information Criterion for small samples (AIC_c); (Burnham and Anderson 2002) to evaluate the support for each of these models. We computed daily nest survival rates (DSRs) for each year using the best logistic-exposure model (Shaffer 2004).

RESULTS

Over all years and fields, 40.6% of visits to fields were nest searches, 32.0% were nest checks, 13.3% were breeding bird surveys, and 14.1% were other research-related activities (n = 752 visits). Nest checks in multi-use fields comprised a substantially lower proportion of the visits than in crane-only fields (13% vs. 53%) because nest checks were usually done during the more extensive nest searches for all nesting waterbirds. Nest searches and "other" activities (usually transect establishment) tended to occur earlier in the year (median date = 20 May) than breeding bird surveys or nest checks (median dates = 1 June for both). Field visits for most activities averaged >2 hr in length: breeding bird surveys, $\overline{x}$ = 154 (SE = 7 min, n = 85 visits); nest checks, $\overline{x}$ = 93 (SE = 8 min, n = 136); nest searches, $\overline{x}$ = 151 (SE = 7 min, n = 265), and other activities, $\overline{x}$ = 155 (SE = 13 min, n = 90).

Median field visit rates for all years was 0.188 field visits/day (range 0.045–3.000; n = 521 nests), which would equate to 5.6 visits over the course of a 30-day incubation period. Those nests with visit rates ≥1 (n = 12) usually had only 1–2 exposure days. Higher field visit rates usually occurred in fields that also were used as pass-through areas to other fields. As expected, field visit rates were higher in multi-use fields (median = 0.240 visits/day; n = 211 nests) than in crane-only fields (median = 0.167 visits/day; n = 310 nests), reflecting the greater level of research activity in those fields. Across all fields, field visit rates were highest in 1998 and lowest in 1997 and 2000 (1997 = 0.167; 1998 = 0.267; 1999 = 0.182; 2000 = 0.167 visits/day), which reflected numbers of waterbird nests found and time required to monitor them each year. Actual direct visits to nests, however, were much lower than visit rates to the field; 96% of all nests and 94% of nests that

survived to hatch were directly visited 1–3 times, and only 17 nests were visited 4 times.

Over all years, we recorded 32.4% of cranes as having flushed from the nest or from near the nest, 6.3% did not flush, and 61.2% were recorded as unknown (n = 2,324 observations). Many responses were unknown because activities were far from some active nests in the field and crane responses were not detected or investigators were quickly passing through a field; the few responses detected during nocturnal amphibian surveys were audible rather than visual. Most (87.8%) cranes with a known response were first detected on the nest; 1.8% were ≤10 m from the nest, 1.8% were 11–50 m away, 2.6% were >50 m from the nest, and 6.1% were not observed or were at an unknown distance from the nest (n = 901). Of those observations of known response (n = 901), 83.7% of cranes were flushed regardless of their location, vis-à-vis the nest, when first detected. Most of the cranes detected on the nest flushed (88.1%), as did cranes ≤10 m away from the nest (81.3%) or >50 m from the nest (78.3%); however, fewer birds observed 11–50 m away from the nest flushed (62.5%). When cranes moved off nests but did not immediately fly away, the most common behavioral responses observed were struts and ruffle-bow-down displays (Tacha et al. 1992). Some cranes would stay 5–20 m away from the investigator and the nest, were obviously very agitated (particularly if young were still at the nest) and often vocalized, but there were no reports of rushing. Among the more aggressive behaviors, uncommonly displayed, were hissing and Directed Walk Threat (Nesbitt and Archibald 1981); some cranes crouched and spread their wings. If activity at or near the nest was prolonged (e.g., >10 min), a crane that had remained in the immediate vicinity usually would fly off to another part of the marsh. We suspect cranes sometimes moved off the nest before we detected them and then flushed as investigators approached close to the nest.

The frequency with which cranes were flushed varied with research activity. Flushing frequency was highest during nest searches (89.4%; n = 526 known responses) and nest checks (87.9%; n = 199) and lowest during bird surveys (68.1%; n = 91) and other activities (54.3%; n = 81). Most cranes with a known response (94.1%; n = 697) flushed during direct nest checks and 28.6% flushed during remote nest checks conducted within the field (n = 35). Other remote nest checks were conducted from outside the field and hence were not included in field visit data.

The median distance at which cranes were observed to flush was 32.5 m (range 5–550 m; n = 471 flushes); half of the distances (25 and 75% quartiles, respectively) were between 20 and 80 m. Median flushing distances tended to be shortest for cranes nesting in open water, upland, and cattail-bulrush and greatest in Baltic rush and sedge; however, distances were variable (Fig. 1). A clearer pattern of flushing distances can be found relative to vegetation height class, but this appeared to be influenced by field type (multi-use vs. crane-only fields; Fig. 2). Flushing distances on crane-only fields were greatest in very short vegetation but differed little once vegetation was >30 cm. In multi-use fields, flushing distance was lower for nests located in the mid-range of vegetation heights and high in very short vegetation and tall vegetation. Overall, mean flushing distances during nest searches and checks on multi-use fields were nearly twice as long as distances on crane-

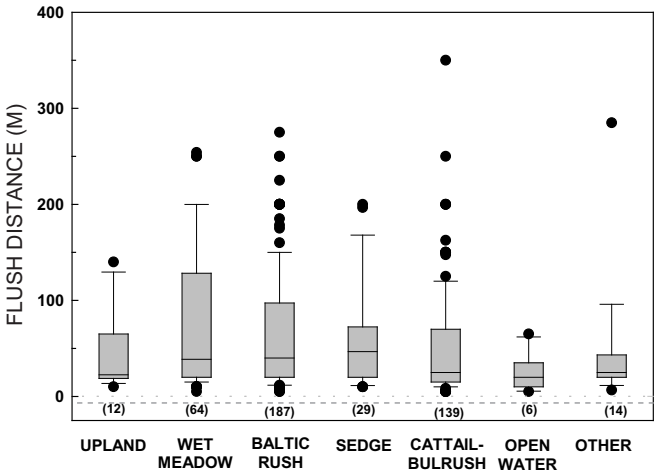

Figure 1. Box plots of estimated flushing distances of sandhill crane at Grays Lake, Idaho, during 1997–2000, by habitat types. Boxes represent 25 and 75% quartiles, whiskers represent 10 and 90% quartiles, and solid dots represent outliers; median flushing distance date is horizontal bar within boxes. Numbers under each box plot represent sample size.

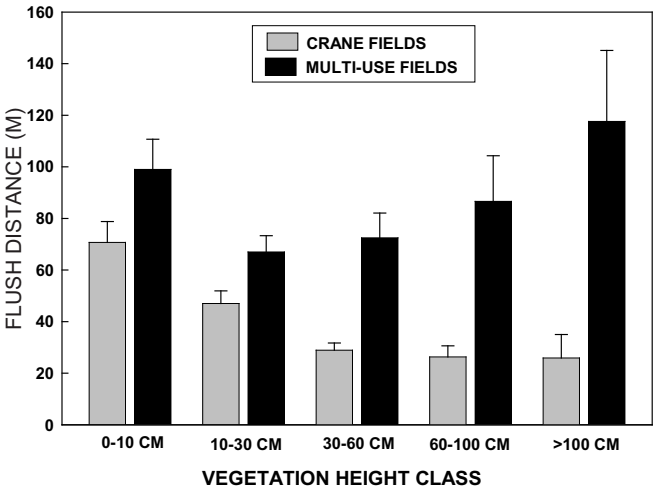

Figure 2. Estimated mean flushing distances (± SE) of sandhill cranes at Grays Lake, Idaho, during 1997–2000, by field type and vegetation height class.

only fields, where most nest searches and checks were done on foot with 1–2 people ($\bar{x}$ = 91, SE = 8 m, n = 124, vs. $\bar{x}$ = 47, SE = 4 m, n = 232; t_{177} = 4.72, P < 0.001). Graphical examination of flushing distance relative to Julian date and vegetation height revealed no apparent patterns. Nor did we find a relationship between the number of visits to which individual nests were exposed and flushing distance using regression (R^2 = 0.002; n = 436).

Of those cranes that were observed to flush (n = 754 observations), their status when observers left the field was largely unknown (45.0%; often flew out of immediate area); 22.0% were >50 m away from their nest; 15.4% were 11–50 m away from the nest; 7.8% were near the nest (≤10 m from the nest), and 9.8% were back on the nest. Flushed cranes were frequently observed to fly long distances (>300 m), often to wet meadow areas where their mate was foraging. Remote observations several hours after departing the field or early the next day indicated most cranes did return to their nest. Only 6 of 578 crane nests monitored during this study were verified as abandoned following investigator disturbance. Abandonment occurred when the investigator visited the nest during egg-laying or during the first 4 days of incubation.

In the analysis of the effects of field visit rate and year on nest survival, the best model included field and year (Table 1). AIC_c values were very similar between this model and the second model (field, year, and field visit rate). However, the second model differs from the first by the addition of 1 parameter (i.e., field visit rate) and the maximum log-likelihoods for the 2 models are nearly equal. Therefore, although the second model is close, the fit to the data is not improved and the model does not support the inclusion of field visit rate as an explanatory factor for nest survival (Burnham and Anderson 2002:131). Daily nest survival rate was highest in 1998 (DSR = 0.9820) and lower in 1999 (0.9684), 2000 (0.9672), and 1997 (0.9666).

Table 1. Logistic-exposure models for nest survival of greater sandhill cranes at Grays Lake, Idaho, during 1997–2000, with corresponding number of parameters (k), log-likelihood values, and Akaike's Information Criterion (AIC_c) scores. Models are ranked by ΔAIC_c values. Model parameters include field (random variable), year, and visit rate.

Model	k	Log-likelihood	AIC_c	ΔAIC_c
Field, Year	5	−477.660	965.3	0
Field, Year, Visit rate	6	−476.743	965.5	0.2
Field, Year, Visit rate, Year*Visit rate	9	−475.424	968.8	3.5

DISCUSSION

During research activities at Grays Lake, the median field visit rate for fields where cranes nested was 0.188 times/day, which is equivalent to 5.6 times over the 30-day period of an active nest that survives to hatch (Drewien 1973). However, most nests were directly visited only 1–3 times. Cranes most often were flushed during direct nest visits and during other research activities. Some birds may have left their nest undetected by observers, leading to underestimating flushing occurrence; indeed, a few cranes on nests located next to cattail-bulrush were observed to sneak off the nest into the taller cover and were not detected by observers nearest the nest (W. Smith, U.S. Fish and Wildlife Service, Wayan, Idaho, personal communication). We believe, however, this situation was not common. It was not possible to make a complete assessment of all responses to field visits by cranes with active nests; some crane nests were not found until a later visit, and some parts of a field were not visible due to topography, vegetation, or distance. Hence, for a large proportion of our visit data, crane response was unknown. If we assume the unknown responses were indeed cranes that were not flushed, the frequency with which cranes were flushed is low (32.4% flushed). We suspect the actual proportion of cranes flushed from their nest or nest area during field visits was much closer to 30% than 80%. In most situations the large size of fields, vegetation height later in nesting, and topography of some fields likely minimized the impact of our presence to all but those crane nests closest to our activity.

If the actual flushing frequency is ~30%, it is not surprising, then, that inclusion of field visit rate to models of nest success was not supported by the model product or outcome. We also had very low occurrences of nest abandonment (1.0%; n = 578 nests) or nonviable eggs (2.3% of nests) (Ball et al. 2003). Nest abandonment occurred primarily very early in the nesting season and for nests found during egg-laying or the first 4 days of incubation. These rates are similar to or lower than those reported elsewhere (Drewien 1973:40, Valentine 1992, Dwyer and Tanner 1992). Despite many field visits associated with multiple research activities during the crane nesting period, we did not find field visit rate to be an important variable explaining nest success in our study. However, field visit rate, as computed here, probably was not a good measure of actual disturbance to a nesting crane. It did not take into account the activity during the visit, visit length, proximity of the observer(s) to active crane nests, or visits to adjacent fields. More conclusive evaluation of the impact of direct visits to the nest would require a manipulative experiment and more detailed information on responses of both members of the crane pair, such as indicated by the study of Nesbitt et al. (2005).

Reduced nesting success related to investigator disturbance

often is associated with increased predation rates, most commonly with avian predators (Götmark 1992). In some studies, avian predators responded to or followed investigators (e.g. Veen 1977, Strang 1980, Götmark et al. 1990, Sedinger 1990) to take advantage of exposed nests. Although common ravens (*Corvus corax*) are known to depredate crane eggs (Tacha et al. 1992) and are common at Grays Lake during the nesting period (Austin et al. 2002), we never noted such behavior and rarely observed common ravens on or near the exposed nests. Ravens instead seemed to avoid areas with human activities, although we did suspect ravens cued into nest markers (Greenwood and Sargeant 1995), which were used only the first year (Ball et al. 2003). Other potential predators of crane eggs at Grays Lake include coyotes (*Canis latrans*), red fox (*Vulpes vulpes*), raccoons (*Procyon lotor*), mink (*Mustela vison*), and American crows (*Corvus brachyrhynchos*) (Tacha et al. 1992); only red fox, ravens, and crows were common (Austin et al. 2002). When observed, these species seemed to move out of areas when investigators were present. Götmark (1992) found little or no evidence for increased predation of bird nests by mammals as a result of investigator disturbance. Thus, we suspect that avoidance responses of predators to investigators at Grays Lake may reduce the potential for depredation of unattended nests.

We did not examine direct links between levels of research activities and success of individual nests because differences between apparent and Mayfield nest success rates (Ball et al. 2003) indicated that we did not find all crane nests despite their conspicuousness in most situations. Alternatively, crane nests in dense emergent vegetation may not have been found because the cranes did not flush; such nests could have been exposed to frequent research activities. Indeed, some cranes nesting in dense bulrush-cattail farther into the marsh did not flush until observers were <5 m away. Three field studies have compared nest success rates of crane nests monitored remotely to those that had been visited during incubation, with differing results. Dwyer and Tanner (1992) reported Mayfield nest success was higher for nests of sandhill cranes that had been visited during incubation than those not visited (41 vs. 64%). Stern et al. (1987) reported that, for 2 of 3 years, apparent nest success was higher for remotely checked crane nests compared to those directly checked nests (28–49% vs. 17–21%). However, they pointed out that many nests that they would have visited failed before they had an opportunity to visit them. Their findings support our concern regarding potential biases of apparent nest success and comparisons of nest success on a nest-by-nest basis. Nesbitt et al. (2005) found nest failure rates of Florida sandhill cranes (*Grus canadensis pratensis*) differed slightly between nests that were directly inspected and those monitored remotely (by air or radio-telemetry; 44% vs. 26%), but these rates did not differ statistically. Time observers spent near nests, time cranes spent off the nest, nest age, and whether the disturbed crane or its mate returned to the nest were associated with probability of nest failure.

The median distance at which cranes flushed was ~30 m, but we found few clear patterns explaining flushing distances. We suspect flushing distance is influenced by a complex of factors including intensity of disturbance (number of people, ATV vs. foot activity), seasonal changes in vegetation height and isolation by water, nest age (Nesbitt et al. 2005), habituation of individual cranes to repeated disturbances (Walkinshaw 1949), and idiosyncratic differences among individual cranes. Other studies reported flushing distances of nesting cranes that tended to be in the lower range of those found for Grays Lake. Sandhill cranes in Florida flushed from their nests when approaching investigators were 3–75 m away (Dwyer and Tanner 1992). In Michigan, Walkinshaw (1949) noted that cranes often would not flush from him until he was <5 m away. The absence of long flushing distances in those studies probably is related to the greater vertical habitat structure (trees and shrubs) and smaller wetland sizes in those areas (see Walkinshaw 1949 for habitat description) compared to the very open, low-structure habitat at Grays Lake.

Although we did examine differences in crane flushing response relative to research activity, we did not quantify the intensity of those activities. Actual disturbance (i.e., causing a behavioral or physiological response; Nisbet 2000) to nesting cranes probably was greater during nest searches on multi-use fields because larger groups of investigators were present (2–5 people, although only 1–2 would inspect a nest) and we often used ATVs and chain drags during nest-searching, particularly later in the season. In contrast, nest searches on crane-only fields were conducted by 1–2 investigators on foot, with minimal use of ATVs. Flushing distances were substantially higher on multi-use fields during nest searches, suggesting greater intensity of disturbance in these fields. Intensity of a potential disturbance likely was lowest when investigators were only traveling through a field (and hence quickly passing by or passing far from most nesting cranes) or during bird surveys, which were point counts conducted entirely on foot. More detailed evaluations of bird responses to research activities during nesting would benefit from quantifying features of each research activity, such as duration, noise level, number of people, transportation type, speed of movements, and proximity of activities to nesting cranes. For example, Burger (1998) and Rodgers and Schwikert (2002) found speed of watercraft affected flight responses of waterbirds; faster watercraft resulted in longer flushing distances.

Our findings suggest a buffer distance of ≥ 50 m between known crane nests and investigators would minimize likelihood of flushing cranes from nests; a larger buffer distance of ≥ 100 m would be needed if ATVs are used. However, buffer widths should be flexible, depending on vegetative cover and local conditions. Large buffer widths may not be

feasible during some activities such as nest searching when full coverage of a field is desired for detecting other nesting species. Alternatively, the flushing distances we found here and those noted in Walkinshaw (1949) indicate that more intensive search effort is needed to detect nesting cranes in heavier vegetative cover. At Grays Lake, cattail-bulrush often occurred in patches <100 m^2, but a thorough search through each patch was needed to detect a nesting crane because they are much less visible and flushed at very short distances. In contrast, we often could readily detect many cranes nesting in habitats of low cover from >100 m away, especially early in the season before regrowth occurred.

We were able to reduce the incidence of flushing cranes from nests by remote nest checks (using binoculars or spotting scopes from ≥ 100 m away). At Grays Lake, remote checks proved valuable for checking a nest several hours or 1 day after visiting a field to determine whether the crane had returned to its nest or abandoned it, and for monitoring nests that otherwise may be exposed to high levels of disturbance (e.g., near a travel lane). Some nests cannot be checked remotely because of topography or vegetation that limits visibility. The benefits of remote checks should be carefully balanced against the need to verify incubation stage, determine egg status (presence and viability), or assess nest fate. We recommend that direct nest checks be made every 7–10 days (i.e. 3–4 times during the life of a successful nest) in order to obtain reliable data. Less frequent visits, or visits only after the nest is believed to have hatched, can result in greater uncertainty in exposure periods and thus less accurate estimates of nest survival. The impact of direct nest visits also can be reduced by minimizing time spent at or near the nest (Nesbitt et al. 2005).

Research activities may have other impacts on nesting waterbirds besides nest success. Research activities or other human disturbances may result in greater time spent alert or flying and less time foraging, and hence higher energetic demands (Belanger and Bedard 1990). Such impacts may be particularly critical for breeding birds that rely on food resources on the breeding grounds for egg production, for adults with young, or for migrant birds in stopover habitats. For territorial species such as sandhill cranes, human activities may push birds into adjacent territories, causing additional strife or mortality. Crane chicks entering into adjacent territories may be killed by adults (Walkinshaw 1981). Hence, caution should be exercised during the chick-rearing period to minimize disruption of foraging activities and displacement of crane families into other territories. However, waterbirds can habituate to research activities or other disturbances over time (e.g. Burger and Gochfeld 1999, Nisbet 2000). Habituation may have occurred for some cranes at Grays Lake, as exemplified by some cranes that nested <20 m from commonly used ATV travel routes. These individuals rarely flushed when ATVs passed by but would flush if approached more closely on foot. Absence of marked birds prevented more detailed investigation of habituation within or among years.

In conclusion, research activities caused many cranes to flush from their nest, thus exposing their eggs to potential predators and sometimes adverse weather conditions. However, our data did not support the inclusion of field visit rate as an important variable explaining nest survival. Also, rates of nest abandonment and egg viability in our study were similar to other studies. Under different situations, research activities may affect crane nest success, particularly if predators become more tolerant of human presence and learn to associate human activities with exposed nests. Future investigators should be aware of the potential impacts of their activities and try to minimize disturbance to nesting birds. Actions to minimize research impacts include limiting the frequency of visits, maintaining a minimum distance to active nests, minimizing time at or near nests, minimizing intensity of disturbance, and using remote nest checks when possible. Additional research, including controls and more comprehensive measures of disturbance and response, is still needed to more conclusively address issues of human disturbances to nesting cranes.

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Laguna de Santiaguillo, Durango, Mexico, an important wintering area for cranes and waterfowl. Photo by Roderick C. Drewien.