Nesting Ecology of Greater Sandhill Cranes *(Grus canadensis tabida)* in Riparian and Palustrine Wetlands of Eastern Idaho

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Abstract.—Little information exists on breeding Greater Sandhill Cranes (*Grus canadensis tabida*) in riparian wetlands of the Intermountain West. We examined the nesting ecology of Sandhill Cranes associated with riparian and palustrine wetlands in the Henry's Fork Watershed in eastern Idaho in 2003. We located 36 active crane nests, 19 in riparian wetlands and 17 in palustrine wetlands. Nesting sites were dominated by rushes (*Juncus* spp.), sedges (*Carex* spp.), Broad-leaved Cattail *(Typha latifolia)* and willow (*Salix* spp.), and adjacent foraging areas were primarily composed of sagebrush (*Artemisia* spp.), cinquefoil (*Potentilla* spp.), Rabbitbrush (*Ericameria bloomeri*) bunch grasses, upland forbs, Quaking Aspen (*Populus tremuloides*) and cottonwood (*Populus* spp.). Mean water depth surrounding nests was 23 cm (SD = 22). A majority of nests (61%) were surrounded by vegetation between 30-60 cm, 23% by vegetation <30 cm, and 16% by vegetation >60 cm in height. We were able to determine the fate of 29 nests, of which 20 were successful (69%). Daily nest survival was 0.986 (95% LCI 0.963, UCI 0.995), equivalent to a Mayfield nest success of 0.654 (95% LCI 0.324, UCI 0.853). Model selection favored models with the covariates vegetation type, vegetation height, and water depth. Nest survival increased with increasing water depth surrounding nest sites. Mean water depth was higher around successful nests (30 cm, SD = 21) than unsuccessful nests (15 cm, SD 22). Further research is needed to evaluate the relative contribution of cranes nesting in palustrine and riparian wetlands distributed widely across the Intermountain West. *Received 14 November 2007, accepted 3 July 2008.*

Key words.—breeding ecology, *Grus canadensis tabida*, Sandhill Crane, Idaho, land management.

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The Rocky Mountain Population (RMP) of Greater Sandhill Cranes (*Grus canadensis tabida*) is distributed throughout southeastern Idaho, western Wyoming, western Montana, northwestern Colorado and northeastern Utah in palustrine and riparian wetlands. Breeding habitat for concentrations of RMP cranes is characterized as "isolated, sub-irrigated-watered river valley, marshes and meadows at elevations above 1,500 m along upper tributaries of the Snake, Bear, Green and Beaverhead river drainages. In addition, hundreds of pairs are scattered along other small drainages and in mountain meadows . . ." (Drewien and Bizeau 1974). Despite such widespread distribution across diverse wetland habitats, our knowledge of crane nesting and nest success in the RMP is entirely limited to palustrine systems, and specifically to Grays Lake, a large palustrine wetland in southeastern Idaho (Steel 1952; Drewien 1973; Austin *et al.* 2007). Indeed, most studies of nesting cranes elsewhere in the United States have been conducted on palustrine wetlands (e.g., Urbanek and Bookhout 1992; Littlefield and Cornely 1996; but see Littlefield 1999 for a study of nesting cranes in riparian wetlands in Oregon).

The diversity of vegetation assemblages and hydrologic regimes associated with extensive, yet relatively uncommon riparian and palustrine wetlands in the northern Rocky Mountains may, cumulatively, contribute significantly to the RMP. Additionally, riparian wetlands may allow cranes to nest successfully despite variation in environmental conditions that negatively effect nest success at large palustrine wetlands such as Grays Lake (Austin *et al.* 2007). Hence, while poorly studied, these wetlands may provide important nesting and foraging habitat for breeding and non-breeding cranes. Riparian and palustrine wetland areas in the northern Rocky Mountains are increasingly impacted by grazing, altered hydrology through irrigation demands and human development (Gude *et al.* 2006; Hansen *et al.* 2002; 2005). From 1970 to 1999, the Greater Yellowstone Area (GYA) experienced a 58% increase in human population and a 350% increase in the area of rural lands supporting exurban housing densities (Gude *et al.* 2006). Because lowland habitats in the GYA are mostly private lands, they are highly desirable for development. As a result, these habitats are rapidly being impacted by the demographic changes occurring at large scales across the GYA and throughout many rural areas of the Intermountain West.

Although many studies have investigated effects of grazing or stream flow on riparian plant and passerine communities, few have addressed the significance of these habitats for wetland birds such as Sandhill Cranes. Moreover, no studies have yet documented nesting success or habitat preferences along these riparian and palustrine wetlands. Therefore, the objectives of our study were to: 1) identify sites where cranes nest in wetlands across the Henry's Fork Watershed in eastern Idaho; 2) describe basic habitat characteristics where crane nests were located; 3) quantify apparent nest success and daily nest survival rate; and 4) evaluate the influence of specific habitat covariates on nest survival.

Several studies of crane nesting ecology document higher rates of nest success with increasing water depth surrounding nests (Austin *et al.* 2007; Drewien *et al.* 1995; Ivey and Dugger 2008; Littlefield 1995 and 2001; Smith and Smith 1992). The mechanism for higher nest survival where nests are surrounded by greater water depths is most commonly thought to be that water effectively isolates nests from common mammalian predators (Sargeant and Arnold 1984; Austin *et al.* 2007). Mammalian predators such as Red Fox (*Vulpes vulpes*), Mink (*Mustela vison*) and Coyote (*Canis latrans*) are commonly observed at both riparian and palustrine wetlands within the Henry's Fork Watershed. Recognizing that mammalian predators are an important factor influencing nest survival, we hypothesized that nest survival would be positively related to water depth surrounding nests. Previous research also suggests that nest success increases within tall vegetation and specific vegetation types (Littlefield and Ryder 1968; Urbanek and Bookhout 1992; Littlefield 2001). Hence, we hypothesized that nest survival would increase with taller vegetation and vegetation associated with deeper water.

We focused our efforts on the Henry's Fork Watershed in eastern Idaho because the watershed contains a number of wetlands supporting numerous species of water birds, it contains wetlands that are representative of regionally rare wetlands found in other lowland valleys in the Intermountain West where little is known about crane nesting ecology and, lastly, it has been identified as one of the most irreplaceable and vulnerable sites within the GYA (Noss *et al.* 2000). Hence, results from our investigations may lead to a better understanding of the role that scattered wetlands play in maintaining populations of cranes occurring in areas especially vulnerable to exurban development.

METHODS

Study Area

The Henry's Fork Watershed is a forested, high mountain plateau (Fig. 1) located in southeastern Idaho in Fremont, Madison and Teton counties and encompasses approximately 700,000 ha. The main rivers

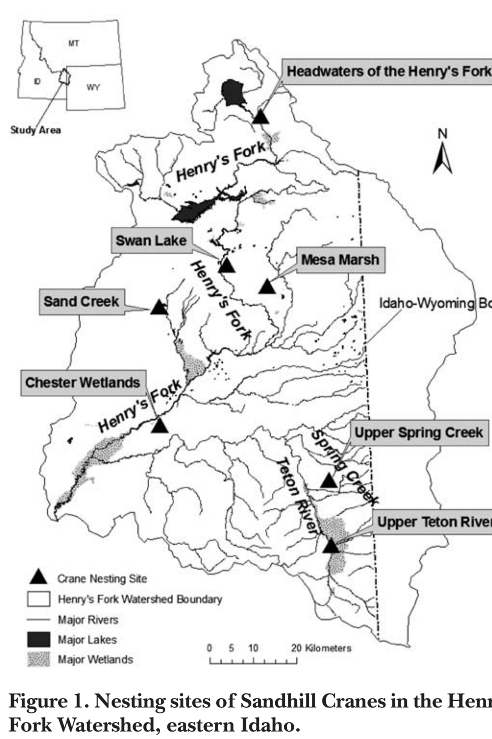

Figure 1. Nesting sites of Sandhill Cranes in the Henry's Fork Watershed, eastern Idaho.

within the watershed include the Henry's Fork of the Snake River beginning at Henry's Lake, the Teton River originating from spring creeks in Teton Valley and the Falls River with its headwaters originating along the west border of Grand Teton National Park.

Elevations in the study area range from about 1,465 m at St. Anthony to about 3,050 m along the Continental Divide. Precipitation at lower elevations of the watershed is nearly uniformly distributed across the year and averages approximately 36 cm annually (Western Regional Climate Center, St. Anthony, Idaho). Precipitation in the higher elevations is greatest during November through June, falls mainly as snow and can average as much as 127 cm annually at the highest elevations, although average annual precipitation in valley wetlands in the upper watershed is approximately 41 cm. Average annual temperatures range from 13 degrees Celsius (average maximum) to -3 degrees Celsius (average minimum).

Preliminary National Wetland Inventory (NWI) data estimate that 9% of the Upper Henry's Fork Watershed, 4% of the Lower Henry's Fork Watershed and 4% of the Teton Basin area consist of riparian and palustrine wetlands (U.S. Fish and Wildlife Service 2006). Most of these wetlands are primarily fed from snowmelt originating in the Teton, Centennial, Lionhead, Palisades and Big Hole Mountains as well as from the Yellowstone Plateau. In addition to runoff, a series of springs contribute a significant amount of water to the Henry's Fork River, with over half of the total discharge above Ashton originating from these springs.

Various forms of development and/or conversion of wetlands, primarily for agricultural purposes, have significantly altered palustrine and riparian wetlands within the Henry's Fork Watershed. Over 3,000 points of water diversion for irrigation have been constructed since the arrival of settlers in the early 1800s, contributing to the loss or extensive modification of 50-90% of riparian habitat (Saab and Groves 1992). The watershed's mountainous areas are mostly forested and are managed by the U.S. Forest Service (USFS) for multiple uses, including timber harvest and recreation. Nearly all of the lower elevation areas of the watershed, historically sagebrush steppe with cottonwood gallery forests along steeper gradients of the riparian areas, are used for agriculture, including livestock operations, dry farming of grain crops and irrigated farming of potatoes and grain.

We identified areas to search for crane nests based on known nesting sites, observations of frequent crane activity during the breeding season and identification of riparian and wet meadows within the Henry's Fork Watershed. Once promising sites were identified, focused nest searches were conducted along riparian and palustrine wetlands near the headwaters of the Henry's Fork of the Snake River, Chester Wetlands, a wetland complex along the Henry's Fork and scattered wetlands along the Teton River in Teton Valley, Idaho.

Nesting Site Descriptions

Sandhill Crane nests were monitored at four riparian and six palustrine wetlands in eastern Idaho (Table 1).

Upper Teton River- The Upper Teton River comprises a complex of wetlands, sloughs, tributary creeks, and a main riparian channel that form the headwaters of the Teton River (Table 1). This section of the river (~20 km long) is characterized as a slow meandering reach

Table 1. Description of riparian and palustrine wetlands where Sandhill Crane nests were located. Ownership acronyms: USFS = US Forest Service; IDFG = Idaho Department of Fish and Game.

Wetland	Description	Dimensions		Ownership	Impounded
		Riparian	*Palustrine*		
Upper Teton River	Riparian	20 km	—	Private	no
Fosters Slough	Riparian slough with adjacent wet meadows	3 km	400 ha	Private	no
Upper Spring Creek	Riparian with adjacent wet meadows	1 km	120 ha	Private	no
Flat Ranch/Henry's Fork Headwaters Area	Riparian with adjacent wet meadows	5 km	647 ha	Private	no
Mesa Marsh	Impounded palustrine wetland	—	58 ha	USFS	yes
Swan Lake	Impounded palustrine wetland	—	12 ha	USFS	yes
Chester Wetlands	Several large playas or palustrine wetlands and adjacent wet meadows	—	40, 15, 5, 3, 1 ha	IDFG	yes
Sand Creek	Impounded palustrine wetland	—	30 ha	IDFG	yes
Beaver Pond	Impounded palustrine wetland	—	2.5 ha	USFS	yes
Lily Pad	Impounded palustrine wetland	—	15 ha	USFS	yes

where sediments from tributaries are deposited. The banks are primarily vegetated by extensive cattails (*Typha* spp.) willow (*Salix* spp.), Hawthorn (*Crataegus douglasii*) as well as upland grasses and forbs.

Fosters Slough- Fosters Slough is a large (~350 ha) wetland complex with a network of spring creeks, irrigation ditches and slough channels that converge to form a primary slough channel before entering the main stem of the upper Teton River (Table 1). The slough is characterized by varied topography, creating gradients from upland Potentilla (*Potentilla fructicosa),* sagebrush, and upland grasses to sedges (*Carex* spp.*),* rushes (*Juncus* spp.*),* cattails, and open water along the slough channel and small areas of open water where the slough ponds up.

Upper Spring Creek- Upper Spring Creek consists of a large (120 ha) extensive open water and shallow flooded emergent wetland habitat (Table 1). There are no willows or other taller shrubs found in this wetland, which is almost exclusively comprised of beaked sedge, Nebraska sedge, spikerush and Baltic rush with small bands of cattails and bulrush along segments of the main channel of Spring Creek. Most of this wetland is flooded for much of May, June and July with >50 cm of water.

Flat Ranch/Headwaters of the Henry's Fork of the Snake River- Henry's Lake drains water from the Centennial and Lionhead mountains to form the headwaters of the Henry's Fork of the Snake River. Water from Henry's Lake meanders through a broad open wetland basin before continuing south towards Island Park. Much of this wetland is found within the Nature Conservancy's Flat Ranch, a 647-ha ranch containing a long riparian corridor (~5 km) dominated by willow species (Table 1). Numerous beaver dams effectively flood hundreds of hectares of wet meadows adjacent to the riparian corridor. These wet meadows consist primarily of rush and sedge complexes.

Mesa Marsh and Swan Lake- The Mesa Marsh (~58 ha) and Swan Lake (~12 ha) wetlands are representative of widely scattered wetlands found within the Caribou-Targhee National Forests between Ashton and Island Park, Idaho (Table 1). Many of these wetlands are characterized by shallow water, supporting large bands of willows, cattails, rushes and sedges around the perimeter of open water areas. Where the hydrology has been influenced by American Beaver (*Castor canadensis*) activity, wetlands support robust willow carrs. Limited cattle grazing occurs in portions of USFS land surrounding Mesa Marsh and Swan Lake.

Chester Wetlands and Sand Creek- The Chester Wetlands and Sand Creek Wildlife Management Area are two properties owned and managed by the Idaho Department of Fish and Game (Idaho Fish and Game) (Table 1). These sites are characterized by broad expanses of dry sagebrush grasslands broken up by playas that are typically ephemeral without management that facilitates ponding or storage. Idaho Fish and Game manages approximately five wetlands at Chester Wetlands and five reservoirs at Sand Creek to provide habitat for Trumpeter Swans and other species, including Sandhill Cranes. Narrow bands of cattail, bulrush and sedge species surround the perimeter of these managed wetlands and small islands of rushes are found in deeper water (>100 cm).

Data Collection

Nest searches were conducted in 2003 during the primary crane breeding season (April-July). Field work was limited to seven days in May, eight days in June and two days in July. Not all sites were visited on each date, and most sites were visited two or three times. Crane nests were located during systematic searches by walking or canoeing or by remote observation using binoculars and spotting scopes. Where searches followed linear riparian corridors, we used a canoe to search a swath approximately 10 m wide along banks for cranes or nests. For all other wetland habitat types, a field crew searched for nests by surveying transects with binoculars and spotting scopes and traversing wetland areas along transects. If a single crane or pair of cranes was observed exhibiting nesting behavior, defensive posturing indicating a possible nest in the vicinity, or adults were observed with chicks, we focused our searches on areas where cranes were first observed. This search technique often led to crane nest sites.

We conducted direct visits to each nest to periodically confirm status of the nest and to determine the incubation stage of eggs. We recorded nest data following forms and a subset of the protocol developed at Grays Lake (Austin *et al.* 2007). We recorded land ownership and habitat type for each nest site and classified habitat type as upland, wet meadow, sedge, Baltic rush/spikerush, bulrush, cattail, sedge/willow, willow, or other. We recorded Universal Transverse Mercator (UTM) coordinates using a handheld global positioning system (GPS) receiver. All nests were considered successful if at least one egg hatched. We determined hatching success by the presence of chicks, tiny shell fragments and/or egg membrane within 5 m of the nest platform. Assuming a 30-day incubation period, we calculated nest initiation dates and hatch dates based on egg floating protocol developed by Tacha *et al.* (1992). During each direct visit to the nest, we recorded the following data: date, nest status, number of eggs, incubation stage, nest fate (hatched, destroyed, infertile), vegetation height class (0-10, 10-30, 30-60, 60-100, or >100 cm), and water depth (cm). We categorized vegetation height based on the height of both residual and new vegetation above the water within a 3-m radius of the nest. We measured water depth in each cardinal direction 1 m from the nest edge and recorded the average.

Analyses

We estimated daily survival rates for nests where we had adequate direct visits to nests. We calculated daily survival rate using PROC NLMIXED in SAS as described by Rotella *et al.* (2004) and Shaffer (2004). This approach allowed us to incorporate data (covariates) associated with each visit interval. The effective sample size for these models was equal to the number of days that all nests survived plus the number of intervals that ended in failure (Rotella *et al.* 2004). We included three covariates thought to be important factors influencing nest survival based on previous studies (Austin *et al.* 2007; Drewien *et al.* 1995; Littlefield 1995; Littlefield 2001; Urbanek and Bookhout 1992): vegetation type, vegetation height and depth of water surrounding the nest. Due to our small sample size, we compared only univariate models without interactions. We evaluated models using Akaike's information criterion (AIC) adjusted for small sample size (AIC_c) and AIC_c model weights (Akaike 1973; Burnham and Anderson 2002). Parameter estimates and their standard errors were calculated using Akaike model weights (Burnham and Anderson 2002).

To assess whether the data supported effects of each covariate of interest on daily survival rate, we examined 95% confidence intervals of parameter estimates to determine the extent to which they overlapped zero. If a variable was present in the best model and parameter estimates and confidence intervals from the best model and from model averaging did not overlap zero, then the relationship of the variable to daily survival rate was considered to be different from zero. If the 95% confidence intervals of either parameter estimate overlapped zero, we considered the relationship between daily survival and the variable to be weak. Model weights were used to gauge the importance of each variable as represented by univariate models (Burnham and Anderson 2002).

RESULTS

Nest Survival

We found 36 active crane nests at selected sites throughout the Henry's Fork Watershed: 18 nests in Teton Basin, eleven in the Ashton-Island Park area, three at Chester wetlands, three at Flat Ranch and one at Sand Creek. Nest initiation dates ranged from 14 April to 19 June. In Teton Basin, eleven nests were successful, two were unsuccessful and five were of undetermined fate. In the Ashton-Island Park area, six nests were successful and five were unsuccessful. All three nests at Chester Wetlands were successful. Sand Creek's one nest was of undetermined fate, and two of three nests at the Flat Ranch were unsuccessful with one of undetermined fate. Apparent nest success varied across vegetation types but was not statistically different across vegetation types at an alpha of 0.05, likely as a result of small sample sizes. Apparent nest success for nests found in rushes was 0.86 (n = 7), sedges 0.75 (n = 8), other 1.0 (n = 2), mixed sedge willows 0.67 (n = 3), cattails 0.60, (n = 5), and willows 0.25 (n = 4).

Nest Site Habitat Characteristics

Nests were distributed across a range of habitat types: sedges (28% of nests), rushes (19%), cattails (19%), willows (14%) and mixed sedge/willow communities (11%). We also found one nest within a water lily bed, one in reed-canary grass (*Phalaris arundinacea)*, and one on a beaver lodge. Water depth surrounding nests averaged 51 cm (SD 33), was highest for nests at the Upper Spring Creek site (58 cm, SD 13) and lowest for nests on the Upper Teton River (6 cm, SD 6) (Fig. 2). Sedges and rushes were associated with the highest mean water depth (38 and 32 cm, SD 19, 26), followed by mixed vegetation of sedge/willows (18 cm, SD 12), willows (12 cm, SD 13) and cattails

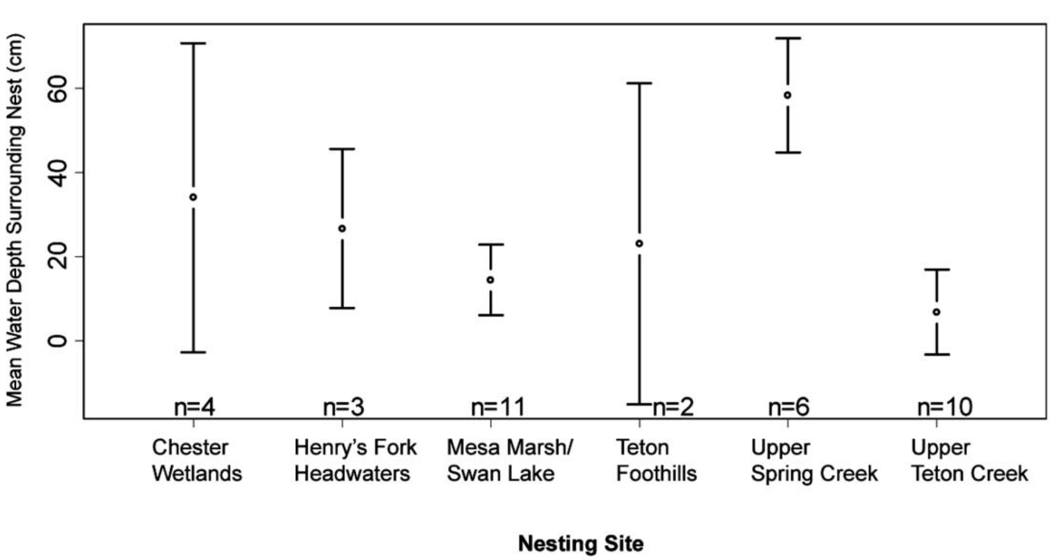

Figure 2. Mean water depth surrounding Sandhill Crane nests at each nesting site within the Henry's Fork Watershed, with 95% upper and lower confidence intervals.

(7 cm, SD 17). Less common vegetation types (water lily, reed-canary grass and beaver lodge), had a mean water depth surrounding nest of 19 cm (SD 23). Vegetation height for most nests (61%) at nest discovery was between 30-60 cm. A smaller percentage of nests were surrounded by vegetation <30 cm (23%) and >60 cm (16%) in height. All nests (n = 3) were surrounded by vegetation >60 cm at Chester Wetlands and half of the nests found along the Upper Teton River had vegetation >60 cm tall. Crane nests were typically found in low numbers, with one or two isolated nests found along a riparian wetland or small palustrine wetland. The greatest numbers of nests were located in cattail bands along the upper Teton River/Foster Slough area and an extensive sedge wetland forming the headwaters of Spring Creek (six nests found at each site).

Of the 29 nests for which we could determine fate, 69% were successful (n = 20) and 31% were unsuccessful (n = 9). Overall Mayfield nest success was estimated at 0.654, (95% LCI 0.324, UCI 0.853; n = 14), and daily nest survival rate was estimated at 0.986, (95% LCI 0.963, UCI 0.995; n = 14). We observed 27 chicks that hatched successfully, for an average of 1.35 chicks hatched per successful nest or 0.93 chicks hatched per nest for all nests where we were able to determine nest fate. Teton Basin nests hatched 14 chicks, Upper Spring Creek nests hatched four chicks, Ashton-Island Park nests hatched seven chicks, and Chester Wetland nests hatched five chicks; Sand Creek and the Flat Ranch had no known hatched young.

Factors Affecting Nest Survival

Vegetation type, vegetation height and water depth univariate models were ranked as the top three models (Table 2). They were all within 2 AIC_c units of each other, were ranked better than the null model (>2 AIC_c units lower than the null model) and shared 95% of the overall model weighting (Table 2). Vegetation type was ranked as the best model with 46% of the model weight followed by vegetation height (28%) and water

Table 2. Logistic-exposure models for nest survival of Greater Sandhill Cranes in the Henry's Fork Watershed, Idaho, during 2003, with Akaike's Information Criterion (AIC_c) scores, delta AIC_c values (difference from "best" model) and model weights, w_i. Models are ranked by ΔAIC_c values.

Model	k	AIC_c	ΔAIC_c	w_i
Vegetation Type	4	18.65	0	0.46
Vegetation Height	2	19.65	1.002	0.28
Water Depth	2	20.26	1.611	0.21
Null	1	23.08	4.426	0.05

tine in SAS did not reach convergence for vegetation type parameter estimates except for cattail (LCI 2.43, UCI 5.50). Plots of daily and overall nest survival across gradients in vegetation height and water depth show that daily and overall nest survival increase as a function of both of these variables (Figs. 3 and 4). Model selection suggests that nest survival is influenced by vegetation type, vegetation height and water depth.

DISCUSSION

The Henry's Fork Watershed is characterized by riparian wetlands and small isolated beaver ponds and wetlands, many of which were created by impoundments and dikes developed by the United States Forest Service (USFS) or Bureau of Land Management (BLM) to facilitate cattle grazing and associated grazing leases. While the wetlands vary widely in their habitat characteristics and distribution across the landscape, we identified several common community assemblages where cranes nest: bulrush-Baltic rush/spikerush and sedge bands surrounding shallow wetlands, beaver-induced wetland ponds along spring creeks, dense cattail bands along the Teton River, mixed willow/sedge bands along riparian corridors and open sedge/rush basins.

Daily survival rates (DSR) of nests in the Henry's Fork Watershed in 2003 (0.986) were higher than DSRs for three of the four years at Grays Lake, Idaho (1997 = 0.97; 1999 = 0.97; and 2000 = 0.97; Austin *et al.* 2007) and similar to the highest DSR at Grays Lake in 1998 (0.98). The high nest survival rates

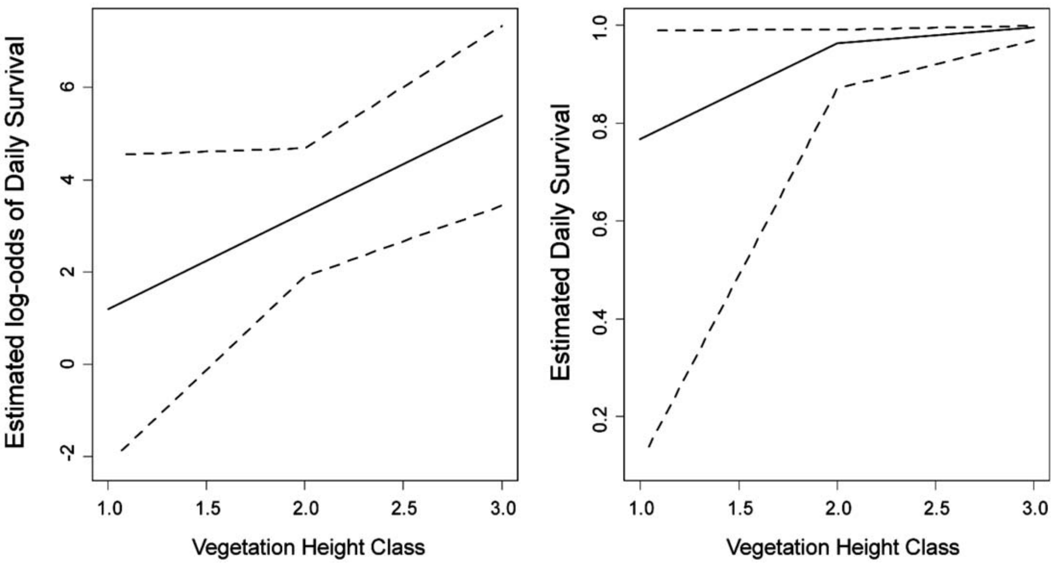

Figure 3. Estimated log-odds of daily nest survival (left plot) and estimated daily nest survival (right plot) of Sandhill Crane nests across a gradient in vegetation height (in height class) with 95% upper and lower confidence intervals shown as dotted lines.

that year at Grays Lake appeared to be due to a combination of high water conditions and high availability of alternative prey (microtines). Model selection results with our data indicate that vegetation type, vegetation height and water depth influence nest survival. However, 95% confidence intervals around these parameter estimates support a positive relationship between water depth and nest survival more clearly than positive correlations with specific vegetation types or vegetation height (Table 3). While vegetation type and height may support higher nest survival through better nest conceal-

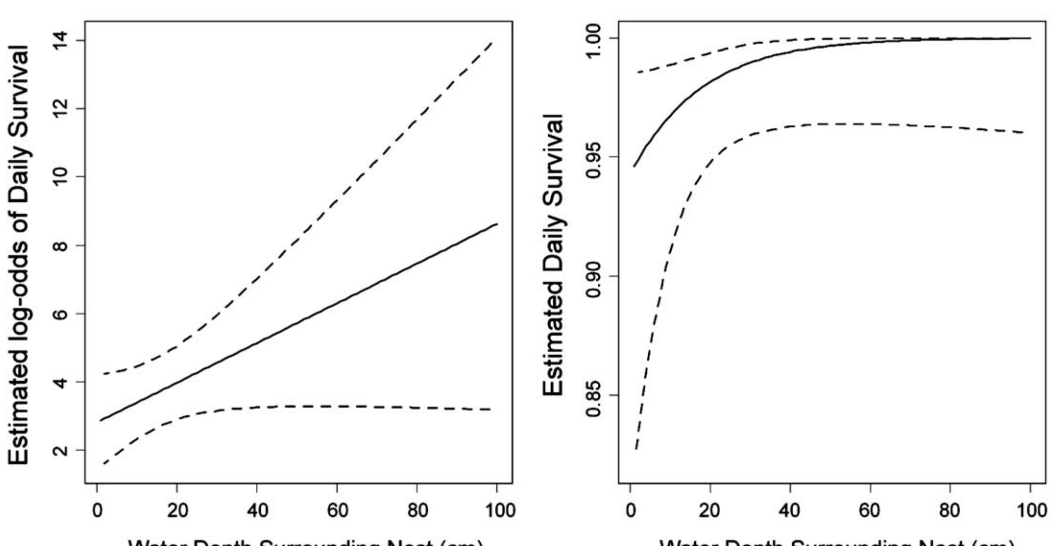

Figure 4. Estimated log-odds of daily nest survival (left plot) and estimated daily nest survival (right plot) of Sandhill Crane nests across a gradient in water depth (cm) with 95% upper and lower confidence intervals shown as dotted lines.

Table 3. Parameter estimates, standard errors and lower and upper 95% confidence intervals (LCI and UCI) for the four models. Non-convergence is noted for upper and lower confidence intervals (nc). We did not obtain convergence in the maximum likelihood routine in SAS for vegetation type parameter estimates except for cattail.

Model	Parameter	Estimate	SE	LCI	UCI
Null	Intercept	4.25	0.51	3.17	5.34
Vegetation Type	Intercept (cattail)	3.96	0.72	2.43	5.50
	Nebraska/Beaked Sedge	28.42	nc	nc	nc
	Sedge/Willow	17.40	nc	nc	nc
	Willow	-53.50	nc	nc	nc
Vegetation Height	Intercept	-0.91	2.87	-7.06	5.23
	Vegetation Height	2.10	1.20	-0.49	4.68
Water Depth	Intercept	2.81	0.71	1.29	4.33
	Water Depth	0.06	0.03	-0.01	0.13

ment from predators, (Littlefield and Ryder 1968; Littlefield 1995; Littlefield 2001) this relationship is less clearly supported by our data.

Similar to the findings at Grays Lake, our results suggest that greater water depth surrounding nests may improve nest survival. Shallow water would provide marginal isolation of nests from mainland areas for mammalian predators and therefore likely facilitates higher rates of depredation. Isolation by deeper water likely prevents mammalian predators from successfully reaching nests, especially when nests are surrounded by deep water several meters wide. We found that most nests located within a primary riparian channel experienced poor isolation during lower water levels in mid-May followed by a period of better isolation as water levels rose following heavy rains on May 24th. Consequently, we speculate that many of these nests were unsuccessful because of the asynchrony of nest initiation and higher water levels that would have improved isolation from mammalian predators.

Sites selected by nesting cranes at Chester Wetlands and Upper Spring Creek appear to provide almost total isolation, with deep (>50 cm) over-water nesting sites in sedges and rushes. Also, extensive sagebrush/grassland areas are available for foraging directly adjacent to these wetlands. Numerous cranes were observed foraging with their chicks along these upland areas. Several nests at Mesa Marsh and Swan Lake also were well isolated by deeper water. We found the lowest water depths around crane nests at the Flat Ranch and the Upper Teton River sites, a condition that likely facilitated mammalian depredation. We observed coyote activity during all three visits to Flat Ranch and during several visits to Upper Teton River sites. We suspect that the combination of low water depths and the presence of numerous predators may limit nest survival within these two sites.

Given the numbers of crane nests we located during nest search efforts, we assume that the density of crane nests in the Henry's Fork Watershed is generally low compared to most areas where nesting cranes have been studied. However, the numerous scattered riparian and palustrine wetlands, including many on public lands (U.S. Forest Service, Bureau of Land Management and Idaho Fish and Game) likely support substantial numbers of cranes. Considered cumulatively, these wetlands may be important in contributing to productivity of the RMP. For all of our nests combined, we recorded higher nest survival rates in 2003, when dry conditions were prevalent throughout the study area, than during three of the four years at Grays Lake. The combination of low spring runoff as a result of less winter precipitation and less than average spring and summer precipitation led to dry conditions in 2003 (Table 4). Data from four different locations within the Henry's Fork Watershed indicate below-average precipitation for both the winter months preceding the 2003 breeding season (affecting runoff) and for precipitation during the breeding season. These dry conditions were apparent during nest visits, es-

Table 4. Mean monthly and cumulative precipitation (cm) for months that most significantly influence breeding-season wetlands (December through June) for 2003, compared to the 30-year mean and cumulative precipitation for the same months (climate data from the Western Regional Climate Center 2007).

Station	2003 Mean	30-yr. Mean	2003 Cumulative	30-yr. Cumulative
St. Anthony	2.46	3.48	17.25	24.33
Driggs	2.34	3.58	16.36	24.99
Island Park	5.54	7.09	38.68	49.58
Ashton	2.90	4.67	20.29	32.64

pecially so for nests found within cattails, where little or no water surrounded nests. Surprisingly, even with below average precipitation, apparent nest success (69%) was greater than that found at Grays Lake National Wildlife Refuge during a period with above-average precipitation (Table 4). The link between nest isolation and natural fluctuations in the depth and flow rate of riparian and palustrine wetlands is likely an important factor affecting crane nest survival.

Another factor that is likely to have a more profound long-term impact on crane productivity is the rapid and extensive exurban development occurring in many important crane breeding grounds in the Intermountain West. Fifty-three percent of nest sites were found on private land (19 of 36), and all of the nests along the Upper Teton River, Upper Spring Creek and Flat Ranch were on private land. While not exempt from the influences of exurban development, nests on contiguous parcels of public land (primarily Caribou-Targhee National Forest) were typically more isolated (>1 km) from private exurban developments.

Increasing development pressures across many rural lowland valley wetlands across the Intermountain West may negatively impact future crane breeding habitat and reproductive success through loss or degradation of habitat, increasing human and predator/dog disturbance and changes to the hydrology of wetlands as a result of changes in water-use and management. These impacts are likely to degrade numerous riparian and small palustrine wetlands scattered across the Intermountain West that may cumulatively play an important role in supporting crane populations. Consequently, it will be important to gather more information about the distribution, habitat use patterns, nest success and productivity from both riparian and small palustrine wetlands throughout the region across multiple years to better understand the contribution that cranes nesting in these wetlands make to the Rocky Mountain Population of Greater Sandhill Cranes. Research investigating the effects of exurban development and associated human disturbance on crane productivity will also be important for assessing the extent to which the RMP is vulnerable to widespread land-use changes that will likely continue to occur in the region.

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