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Reviewed work(s):

Source: *The Condor*, Vol. 112, No. 4 (November 2010), pp. 825-833

Published by: [University of California Press](#) on behalf of the [Cooper Ornithological Society](#)

Stable URL: <http://www.jstor.org/stable/10.1525/cond.2010.100148>

Accessed: 14/10/2012 16:05

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ESTIMATING THE ABUNDANCE OF NESTING RUSTY BLACKBIRDS IN RELATION TO WETLAND HABITATS IN ALASKA

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Abstract. We used double sampling to estimate densities of Rusty Blackbird (*Euphagus carolinus*) nests among boreal wetlands in Anchorage and Tanana Flats, Alaska, 2007–2008. We also assessed habitat selection by examining the number and location of nests relative to the availability of various wetland types. We rapidly surveyed 78 sample units for adult Rusty Blackbirds and intensively searched for nests in a subset of 55 units to determine actual numbers of nests. Rapid surveys detected 97% of the 75 nests when we restricted counts to pairs and lone females. They overestimated nest numbers by 17% when we included in the counts lone males, which sometimes made long flights within and between sample units. Nest densities in sampled wetlands averaged 2.2 and 3.4 nests km⁻² in Anchorage and Tanana Flats, respectively, surprisingly similar despite wetlands being rare in Anchorage. An abundance of wetlands made identifying important breeding habitats difficult on the Tanana Flats, where blackbirds used most wetland types in relation to their availability and avoided wetlands with low shrubs. Habitat selection was clearer in Anchorage, where ponds, lakes, and wetlands with emergent vegetation were positive predictors of nest abundance. In this area blackbirds also selected forested wetlands and avoided upland habitats for nest sites. An affinity for open water has been noted throughout the Rusty Blackbird's breeding range. Research is needed to understand whether this affinity is due to specialized food requirements and to assess whether this species is vulnerable to widespread drying of wetlands across boreal Alaska.

Key words: Alaska, boreal wetlands, double sampling, *Euphagus carolinus*, habitat selection, nesting abundance, Rusty Blackbird.

Estimaciones de Abundancia de Individuos Anidando de *Euphagus carolinus* con Relación a Hábitats de Humedales en Alaska

Resumen. Usamos un muestreo doble para estimar las densidades de nidos de *Euphagus carolinus* en humedales boreales en Anchorage y las Planicies de Tanana, Alaska, entre 2007 y 2008. También evaluamos la selección de hábitat al examinar el número y la ubicación de los nidos con relación a la disponibilidad de varios tipos de humedales. Censamos rápidamente 78 unidades de muestreo de *E. carolinus* adultos y buscamos intensivamente nidos en un subgrupo de 55 unidades para determinar la cantidad real de nidos. Los muestreos rápidos detectaron un 97% de los 75 nidos cuando restringimos los conteos a parejas y hembras solitarias. Los muestreos sobreestimaron la cantidad de nidos en un 17% cuando incluimos en los conteos a los machos solitarios, los que a veces realizaron vuelos dentro y entre las unidades. Las densidades de nidos en los humedales muestreados promediaron 2.2 y 3.4 nidos por km² en Anchorage y las Planicies de Tanana, respectivamente, siendo sorpresivamente similar a pesar de que los humedales son poco comunes en Anchorage. La abundancia de humedales hizo difícil la identificación de hábitats de reproducción importantes en las Planicies de Tanana, donde *E. carolinus* utilizó la mayoría de los tipos de humedales con relación a su disponibilidad y evitó los humedales con arbustos bajos. La selección de hábitat fue más clara en Anchorage, donde los estanques, lagos y humedales con vegetación emergente predijeron positivamente la abundancia de nidos. En esta área, los individuos de *E. carolinus* también seleccionaron los humedales forestados y evitaron los hábitats de tierras altas como sitios de anidación. Se notó una afinidad por las aguas de espacios abiertos a lo largo del área reproductiva de *E. carolinus*. Es necesario investigar para entender si esta afinidad se debe a requerimientos alimenticios específicos y para evaluar si esta especie es vulnerable a la desecación generalizada de los humedales a lo largo y ancho de la Alaska boreal.

INTRODUCTION

Steep rangewide declines of the Rusty Blackbird (*Euphagus carolinus*; Greenberg and Droege 1999, Greenberg et al. 2011) have recently spurred interest in identifying for conservation

those geographic locations and habitats that support high densities of the species (Greenberg 2008, Greenberg et al. 2011). The Rusty Blackbird breeds across North America's vast and remote boreal forest (Blancher and Wells 2005), where little is known about its natural history and specific habitat requirements.

Manuscript received 30 July 2010; accepted 11 August 2010.

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Broad-scale avian surveys, such as the roadside North American Breeding Bird Survey, are not well suited for estimating the abundance of or habitat use by breeding Rusty Blackbirds because of the species' patchy distribution, solitary breeding habits, and use of boreal wetlands, which are frequently remote and inaccessible (Greenberg et al. 2011). The localized surveys that have included the species (Erskine 1977, Spindler and Kessel 1980, DesGranges and Houde 1989, LaRue et al. 1995, Whitaker and Montevecchi 1997, 1999) have not been corrected for incomplete detectability and may therefore be biased to some unknown degree (Machtans et al. 2007). Thus, there is a need for survey methods that better estimate Rusty Blackbird abundance and patterns of habitat use during the breeding season.

In this study, we estimate the abundance of nesting Rusty Blackbirds relative to various wetland types by using a double-sampling technique developed for estimating densities of shorebirds breeding on the remote North Slope of Alaska (Bart and Ernst 2002, Brown et al. 2007). This method involves obtaining two samples of counts from (1) a number of survey units that are rapidly searched for breeding pairs and (2) a subsample of these survey units that are also intensively searched to determine actual numbers of nesting pairs. The ratio of the counts from rapid surveys to those from intensive searches provides a detection ratio, which is then used to correct the counts across the entire sample of rapidly surveyed units and thereby provide an unbiased estimate of the number of nesting pairs (Bart and Ernst 2002). We chose the double-sampling technique in favor of others because we expected that in most surveys the number of Rusty Blackbirds encountered would be insufficient for estimation of densities by distance sampling (Buckland et al. 2001, Machtans et al. 2007) and we anticipated that variation in the counts might provide important information on habitat selection that might otherwise be lost if the counts were reduced to presence versus absence and then used in occupancy models (MacKenzie et al. 2006). Our specific objectives were to (1) assess double sampling as a means of estimating the abundance of nesting Rusty Blackbirds and (2) identify those wetland types that predict nesting abundance and nest-site selection. We conducted our study in two contrasting boreal landscapes in Alaska to assess double sampling over a range of conditions and to compare patterns of blackbird abundance and habitat selection in a wetland- and an upland-dominated landscape.

METHODS

STUDY AREA

We conducted our field work at the Tanana Flats Training Area of Fort Wainwright (Tanana Flats, 64° 45' N, 147° 45' W) near Fairbanks in interior Alaska and at Fort Richardson and adjacent Elmendorf Air Force Base in Anchorage, Alaska (Anchorage, 61° 15' N, 149° 41' W). The Tanana Flats are within the expansive floodplain of the Tanana River and include a

mosaic of poorly differentiated and large wetlands that are flooded annually. Both upland habitats and ponds and lakes are uncommon in the study area. Surface water is found in wet graminoid meadows, fens dominated by floating mats of wetland vegetation, and slow tributaries of the Tanana River. Willows (*Salix* spp.) and green alder (*Alnus viridis*) are the common wetland shrubs >1 m in height. Balsam poplar (*Populus balsamifera*) and paper birch (*Betula papyrifera*) are the dominant trees in forested wetlands; black (*Picea mariana*) and white (*P. glauca*) spruce are fewer. This military training area was not accessible by road.

At Anchorage, the wetlands are variable in size, isolated, and dispersed across a primarily upland landscape dominated by boreal forest. Surface water is largely limited to ponds, lakes, and estuaries and nearby areas with shallow water and emergent wetland vegetation. The plant species in Anchorage wetlands are similar to those on the Tanana Flats, but black spruce is more common and willows (>1 m in height) are less common (Matsuoka et al. 2010). At Anchorage, all wetlands were accessible by road, foot, or canoe. The plant and bird communities of Fort Richardson have been described in detail by Jorgenson et al. (1998a) and Andres et al. (2001), those of Fort Wainwright by Jorgenson et al. (1998b) and Benson (1999).

To allocate our sampling, we first obtained digital georeferenced data for Anchorage from the National Wetlands Inventory (NWI; Cowardin et al. 1979) and for the Tanana Flats from land classifications based on Viereck et al. (1992) developed for this site by Jorgenson et al. (1998b). We then used these data to identify wetlands, calculate their area, and differentiate wetland classes. We used different land-cover classifications for the two study areas because NWI had the only data that covered the entire Anchorage study area and we found that for the Tanana Flats the land classifications by Jorgenson et al. (1998b) were more accurate than those by the NWI. Because of differences between the two study areas in wetland landscapes and accessibility, we took different approaches in defining and selecting the sample units that we surveyed for breeding Rusty Blackbirds and subsequently searched for nests. On the Tanana Flats, wetland habitats for nesting were abundant. We therefore laid a grid of squares 500 m on a side (25 ha) across the study area and selected for surveys the 45 squares (total area of 11.25 km²) that were within 3 km of and accessible by foot from our remote field camp.

In Anchorage, wetlands were typically isolated, so we identified individual wetlands as potential sample units. We selected for sampling all wetlands that were seasonally or permanently flooded because Rusty Blackbirds had been previously observed to feed and nest near these habitats (Kennard 1920, Gabrielson and Lincoln 1959, Avery 1995, Machtans et al. 2007). These habitats included the shores of estuaries, ponds, and lakes and palustrine wetlands with emergent wetland vegetation or seasonally flooded shrublands or forests. We added to each of these units a 50-m buffer to encompass

potential nesting sites in adjacent uplands or wetlands with saturated soils. When the buffers of nearby wetlands overlapped, we combined them into a single sample unit. This procedure resulted in the selection of 33 sample units ranging from 1.1 to 139.2 ha in area ($\bar{x} = 29.4 \pm 6.1$ ha) and totaling 9.67 km². We excluded the area of lakes and ponds in these when calculating the size of the sample unit because these were unavailable for nesting. We did not expect Rusty Blackbird to nest in the sample units lying in the low end of this size range; however, we wanted to determine the minimum size of wetlands that birds used for breeding in the study area.

FIELD METHODS

We used double sampling (Handel and Gill 1992, Bart and Ernst 2002, Brown et al. 2007) to estimate the number of pairs of Rusty Blackbirds nesting in Anchorage in 2007 and 2008 and on the Tanana Flats in 2008. This procedure entailed two sets of surveys, (1) rapid surveys of sample units to generate raw counts and (2) nest searches on a subset of these sample units to determine actual numbers of nesting pairs. In Anchorage, in 2007 we conducted rapid surveys and searched for nests in all 33 sample units. In 2008 we conducted rapid surveys of a subset of 23 sample units ($\bar{x} = 37.0 \pm 7.9$ ha, total area sampled = 852 ha) and searched for nests in all of the sample units in which we detected territorial adults during our rapid surveys in either 2007 or 2008. We excluded from sampling (1) seven units <4 ha in area because they did not host nesting blackbirds in 2007 and (2) three sample units to which military activities restricted regular access.

On the Tanana Flats, in 2008 we conducted a single rapid survey of 45 sample units and nest searches in a subsample of 22 units. The latter included the 11 sample units with the highest counts of pairs of blackbirds during the rapid surveys and a random selection of 11 additional sample units that were near these. In 2007, we searched for nests but did not rapidly survey for blackbirds in 13 of these sample units on the Tanana Flats. We did not include these data in our analyses of abundance based on double sampling but did include the locations of the nests from 2007 in our analyses of nest-site selection (see Statistical Analyses).

We conducted our rapid surveys between 06:00 and 13:00 and from 11 to 23 May, the period from pair formation to early incubation (Matsuoka et al. 2010) and the time when we expected detection rates to be relatively high because most females would not yet be incubating their eggs and most males would still be actively singing and closely guarding their mates. We did not constrain our surveys to the early morning because previous work indicated that detectability of breeding Rusty Blackbirds does not vary over the morning (P. Blancher, unpubl. data; C. S. Machtans, unpubl. data). We conducted rapid surveys at a rate of 10 ha hr⁻¹, walking a path passing within approximately 100 m of all points in a unit. We mapped on aerial photos the sex, movements, and behaviors of each adult Rusty Blackbird we encountered. We took special care

to distinguish our observations of pairs from those of lone individuals and to map our simultaneous observations of two or more birds to help distinguish neighboring pairs after they had moved (Ralph et al. 1993). In Anchorage, when possible, we also surveyed the shorelines of the larger lakes by canoe. At the end of each survey we classified the birds detected by sex and whether they were paired, then tallied the total number of observed pairs, lone territorial males, and lone females in the survey unit (Bart and Ernst 2002). We excluded from the tally any males that did not behave territorially, any adults observed only flying over the sample unit, and any adults that we first detected taking long flights (>100 m) into the survey unit from adjacent areas. We excluded the last to minimize the probability of individuals in nearby survey units being double counted (Machtans et al. 2007).

We searched for nests in a subset of sample units from 15 May to 5 June. In Anchorage, we made one or three visits for nest searching, one when we did not detect adult blackbirds on either the rapid survey or during this nest search, three when we detected adults on either the rapid survey or the initial nest search. On the Tanana Flats we made three nest searches on each selected unit. During each visit we concentrated our searches on wet meadows and the edges of water bodies—habitats where we typically observed adults during the rapid surveys. When we encountered adults during nest searches we observed their activities from a distance, mapped their location, movements, and behaviors, and followed them back to their nests as they carried nesting materials, returned to incubate eggs, or provisioned their mates or young with food. We recorded the location of each nest in a global-positioning system. We sometimes found additional nests in our sample units when we visited nests to monitor their survival (Matsuoka et al. 2010). These additional nests were nearly always in areas where we had encountered pairs whose nests we failed to find during our previous nesting searches. For each sample unit we determined the actual number of nesting pairs by summing the number of nests and the number of territorial pairs in the unit whose nest we could not find. We did not include in these tallies those nests that we suspected from their chronology and location relative to known failed nests to be attempts at renesting.

STATISTICAL ANALYSES

We first evaluated the accuracy of the rapid surveys by examining the data from the subset of sample units in which we conducted both rapid surveys and nest searches. We did this by calculating, for each study area and year, a detection ratio (\hat{p}) as the number of breeding pairs counted during rapid surveys divided by the actual number of nesting pairs counted during nest searches (Cochran 1977, Bart and Ernst 2002). We grouped our counts of birds during the rapid surveys into four classes—observed pairs, observed pairs plus lone females, observed pairs plus lone territorial males, and observed pairs plus lone females and lone territorial males—and calculated

the detection ratio for each class to determine which combination of counts resulted in a detection ratio closest to 1. We then used the combination of counts that minimized bias and further evaluated the accuracy of the unadjusted rapid surveys by calculating the proportion of sample units that the surveys correctly classified as used versus not used by nesting pairs of Rusty Blackbirds.

We then used \hat{p} to correct our rapid survey counts and estimated the density and total number of nesting pairs for each study area (Bart and Ernst 2002). For the Tanana Flats, we restricted our estimates to the 11.25-km² area we surveyed because it was not representative of the entire training area. For Anchorage, we sampled all suitable wetlands in the study area. We therefore used the mean of the 2007 and 2008 nest counts for each sampled unit and estimated densities at two scales, the immediate wetlands surveyed (9.67 km²) and the entire study area (243 km²) in Anchorage.

We used Poisson regression to assess whether the availability of each wetland class was a strong predictor of the number of pairs of blackbirds nesting in a sample unit. The wetland classes that we evaluated for the Anchorage study area were the surface area (ha) of ponds and lakes and the area (ha) of wetlands with emergent vegetation, scrub-shrub wetlands, forested wetlands, and upland habitats. For Anchorage, we used the maximum number of actual nesting pairs in each sample unit (2007 and 2008) as the response variable and included the log of the area of the sample unit (ha) as an offset to account for variation in the area of sample units (Jones et al. 2002). For the Tanana Flats, the wetland classes that we evaluated were the area (ha) of rivers, graminoid meadows (meadows), wetlands dominated by low shrubs (low shrub wetlands), tall shrubs along rivers (tall-shrub wetlands), and forested wetlands. On the Tanana Flats we used a combination of actual numbers of nesting pairs and unadjusted rapid-survey counts as our measure of abundance. We used the actual number of nesting pairs for the 22 survey units that we intensively searched for nests. We used the unadjusted count of observed pairs plus lone females for units that we surveyed only rapidly because we found it to be representative of the number of nesting pairs (see Results). We did not include an offset in the models for the Tanana Flats because all sample units were of equal size. We fit all univariate and bivariate combinations of explanatory variables for each study area and compared the relative fit of models for each study area with Akaike's information criterion adjusted for small sample sizes (AIC_c) and rescaled as AIC_c differences (Δ_i) and model probabilities (w_i). To assess the overall evidence that a variable was associated with abundance, we summed w_i of models sharing a common explanatory variable (Σw_p , Burnham and Anderson 2002).

We examined the selection of habitats for nest sites separately for each study area by comparing the frequencies at which blackbirds used each wetland class for nest sites versus the availability of each class in the sample units that we surveyed. For each study area, we pooled nests across sample

units, years, and first and second nesting attempts because of small sample sizes and used log-linear models with a Poisson distribution and log-link function (Agresti 1990) to examine departures of use from availability. We then followed Manly et al. (1993) and developed a null model that included two variables, use (nest vs. available) and wetland class (total hectares surveyed of each wetland class), which allowed the number of samples to vary by use and available categories. We then compared the AIC_c values of the null model and one that added the interaction, use \times wetland class, which tests for selection by allowing proportional use of the wetland classes to vary from proportional availability. When we found support for models with selection, we used the methods of Manly et al. (1993) to compute and compare standardized selection functions.

We used SAS version 9.2 (SAS Institute 2008) to calculate descriptive statistics and develop predictive models and ArcGIS version 9.0 to estimate the area of the wetland classes for each survey unit. We present all estimates \pm SE and considered models with $\Delta_i \leq 2$ to be best supported by the data (Burnham and Anderson 2002).

RESULTS

DOUBLE SAMPLING

We conducted both rapid surveys and nest searches on a total of 55 sample units in 2007 and 2008. In Anchorage, we sampled 10 of these units in both 2007 and 2008. We counted 66 pairs, 15 lone territorial males, and seven lone females during our rapid surveys. During our nest searches in Anchorage in 2007 and 2008 and the Tanana Flats in 2008, we found a total of 70 first nests and five territorial pairs whose nests we could not find (Table 1). We found that the rapid survey estimated the actual number of nesting pairs best when we restricted the count to the number of pairs plus the number of lone females (Table 1). On the basis of this count, the rapid surveys detected $90 \pm 12\%$ of the actual nesting pairs in Anchorage, $106 \pm 16\%$ of actual pairs on the Tanana Flats, and $97 \pm 10\%$ of actual pairs for the study areas combined. This count also correctly classified 88% of sampled units as used by nesting pairs, 94% of the units as not used by nesting pairs, and 91% of the units combined.

The rapid surveys were generally not as accurate when the count was based on other combinations of our observations (Table 1). When we restricted the rapid surveys to counts of observed pairs, they underestimated abundance in Anchorage ($81 \pm 11\%$ of actual pairs detected) and for the study sites combined ($88 \pm 9\%$) but were quite accurate for the Tanana Flats ($97 \pm 16\%$). With sites and years combined, the rapid survey overestimated the number of actual nesting pairs when the count was based on observed pairs plus territorial males ($108 \pm 11\%$ of actual pairs) and observed pairs plus lone females and territorial males ($\hat{p} = 117 \pm 11\%$).

We used \hat{p} for each study area to correct the rapid counts of observed pairs plus females. The density of nesting pairs

TABLE 1. Comparisons of detection ratios ($\hat{p} \pm SE$) of nesting pairs of Rusty Blackbirds counted during rapid surveys of nest-searching plots in Anchorage and the Tanana Flats, Alaska. The actual count is the sum of first nests found ($n = 70$) and territorial pairs ($n = 5$) with territory centroids in our survey units but whose nests we did not find.

Unit of observation ^a	Anchorage				Tanana Flats		Sites and years combined		
	2007 ($n = 33$ surveys)		2008 ($n = 10$ surveys)		2008 ($n = 22$ surveys)		$n = 65$ surveys)		
	Count	\hat{p}	Count	\hat{p}	Count	\hat{p}	Count	\hat{p}	SE
Pairs	17	0.81	17	0.81	32	0.97	66	0.88	0.09
Pairs and lone females	19	0.90	19	0.90	35	1.06	73	0.97	0.10
Pairs and lone males	23	1.10	18	0.86	40	1.21	81	1.08	0.11
Pairs + lone males and females	25	1.14	20	0.95	43	1.30	88	1.17	0.11
Total birds	42		37		75		154		
Actual number of pairs	21		21		33		75		

^aDuring our rapid surveys most of our observations were of pairs in which males were closely guarding females ($n = 66$ detections); we detected smaller number of lone females ($n = 7$) and lone territorial males ($n = 15$).

over the area sampled and the total number of actual nests in Anchorage in 2007 were 2.2 ± 1.0 pairs km^{-2} and 21.0 ± 9.6 nests, respectively ($n = 33$ survey units). Extrapolated across the military lands in Anchorage, density averaged 0.09 ± 0.04 pairs km^{-2} . When we restricted our analysis of the Anchorage data to the survey units sampled in both 2007 and 2008, density averaged 2.5 ± 1.1 pairs km^{-2} ($n = 23$ units), which was 73% of the average density of 3.4 ± 0.9 pairs km^{-2} ($n = 45$ units) on the Tanana Flats in 2008. We estimated that there were a total of 38.7 ± 9.8 pairs of Rusty Blackbirds nesting on the surveyed portion of the Tanana Flats in 2008. Densities of nesting pairs in survey units with blackbirds varied from 2.7 to 24.2 pairs km^{-2} in Anchorage ($n = 8$ survey units) and from 4 to 12 pairs km^{-2} on the Tanana Flats ($n = 25$ survey units).

PREDICTIVE MODELS OF ABUNDANCE

In Anchorage, a Poisson regression that included lakes and ponds and wetlands with emergent vegetation best predicted the count of actual nesting pairs in the Anchorage study area (log-likelihood [L] = -9.9 , $n = 33$ survey units, number of parameters [K] = 4, $AIC_c = 27.9$, $w_i = 0.47$). This model indicated that the number of nesting pairs in a unit increased with the area of lakes, ponds, and emergent vegetation (Table 2). Survey units with nesting pairs had 10 times the mean surface area of lakes and ponds and 1.5 times the mean area of emergent vegetation than survey units without nesting pairs (Table 3). This model was only slightly better than the next best model, which included lakes and ponds and uplands ($L = -10.5$, $K = 4$, $\Delta_i = 1.1$, $w_i = 0.27$), but was >1000 times more likely than the model with only an intercept ($L = -19.7$, $K = 2$, $\Delta_i = 14.5$, $w_i < 0.01$) and 7 times more likely than the univariate model with lakes and ponds. The second-best model indicated that the number of nesting pairs increased with the area of lakes and ponds ($\beta = 0.05 \pm 0.01$) but decreased with increases in the area of upland habitats ($\beta = -0.04 \pm 0.02$). All

TABLE 2. Parameter estimates for the Poisson regression models that best predicted the maximum number of Rusty Blackbird pairs breeding in Anchorage, Alaska, 2007–2008, and Tanana Flats, Alaska 2008. The log of the size of the survey units (ha) was used as an offset to account for differences in survey effort among survey units in Anchorage.

Variable	Estimate	SE	P
Anchorage			
Intercept	-5.03	0.48	<0.001
Lakes and ponds	0.04	0.01	<0.001
Emergent vegetation wetland	0.03	0.01	0.01
Tanana Flats			
Intercept	0.26	0.19	0.18
Low shrub wetland	-0.10	0.04	0.01

other models had $\Delta_i \geq 2.4$. Summing model weights, we found strong support for models that included the surface area of lakes and ponds as a predictor of abundance ($\beta w_i = 1.00$). We found less support for models with emergent vegetation wetlands ($\Sigma w_i = 0.47$), upland habitat, shrub wetlands, or forested wetlands ($\Sigma w_i \leq 0.27$; Table 3).

On the Tanana Flats, a Poisson regression that included low-shrub wetlands best predicted the count of nesting pairs with the count decreasing as the area of low shrub wetlands in a sample unit increased ($L = -40.0$, $n = 45$ survey units, $K = 3$, $AIC_c = 86.6$, $w_i = 0.35$; Table 2). Survey units with nesting pairs had 41% of the mean area of low-shrub wetlands found in survey units without nesting blackbirds (Table 3). This model was equivalent to the next-best model, which included the areas of shrub wetland and meadow ($L = -39.6$, $K = 4$, $\Delta_i = 1.6$, $w_i = 0.16$), and was 31 times more likely than the model with only an intercept ($L = -44.6$, $K = 2$, $\Delta_i = 6.8$, $w_i = 0.01$). Summing model weights, we found the most support for models that included low-shrub wetlands as a predictor of abundance ($\Sigma w_i = 0.89$). We found far less support for models

TABLE 3. Average area (ha) of wetland types on survey units used and not used by Rusty Blackbirds in Anchorage, 2007–2008, and Tanana Flats, 2007, Alaska.

Study area/wetland type ^a	Used	Not used	Σw_i^b
Anchorage	(<i>n</i> = 8 units)	(<i>n</i> = 25 units)	
Lakes and ponds	19.7 ± 8.9	1.9 ± 0.7	1.00
Emergent vegetation wetland	5.3 ± 2.7	3.6 ± 1.9	0.47
Shrub wetland	13.4 ± 8.5	9.1 ± 3.3	0.14
Forested wetland	2.5 ± 0.8	1.4 ± 0.8	0.05
Upland	19.2 ± 5.8	10.2 ± 1.9	0.27
Tanana Flats	(<i>n</i> = 25 units)	(<i>n</i> = 20 units)	
River	0.7 ± 0.2	0.4 ± 0.2	0.14
Sedge meadow	9.5 ± 1.2	6.2 ± 1.4	0.22
Low shrub wetland	3.3 ± 0.9	8.1 ± 1.4	0.89
Tall riparian shrub	5.5 ± 1.3	3.1 ± 1.0	0.18
Forested wetland	6.0 ± 1.2	7.1 ± 1.2	0.17

^aIn Anchorage we used covariates based on wetland classifications from the National Wetland Inventory (Cowardin et al. 1979). On the Tanana Flats we used covariates based on land classifications by Jorgenson et al. (1998b).

^bWe compared the relative importance of wetland types as predictors of the number of breeding pairs by summing model weights (Σw_i) among all univariate and bivariate Poisson regressions calculate separately for each study area.

with meadow, forested wetlands, rivers, or upland habitats ($\Sigma w_i \leq 0.22$; Table 3).

SELECTION OF WETLAND TYPES FOR NESTING

In our analysis of nest-site selection we included the 70 first nests included in our analysis of double sampling (Table 1), 21 nests that we found on the Tanana Flats in 2007, and four second nests from Anchorage and one second nest from the Tanana Flats that we found in 2008. In Anchorage, we found most of the Rusty Blackbird nests in shrub-scrub wetlands;

we found fewer nests in each of the other classes of wetlands (Table 4). The log-linear model that included selection of wetland classes ($L = -22.3$, $n = 43$ nests and 933 ha of the wetland classes surveyed, $K = 9$, $AIC_c = 62.8$) was 140 times more likely than the null model of no selection ($L = -30.3$, $K = 6$, $\Delta_i = 9.9$). Comparisons of the standardized selection coefficients indicated that, in Anchorage, Rusty Blackbirds were 7.4 times more likely to select nest sites in forested wetlands than in upland habitats, which they tended to avoid. Nests were located in emergent and shrub-scrub wetlands in proportion to availability (Table 4).

On the Tanana Flats, we found most nests in meadows and forested wetlands, intermediate numbers in tall-shrub wetlands, and few nests in low-shrub wetlands (Table 4). The log-linear model that included selection of wetland classes ($L = -23.3$, $n = 54$ nests and 1099 ha of the wetland classes surveyed, $K = 9$, $AIC_c = 64.8$) was 23 times more likely than the null model of no selection ($L = -29.5$, $K = 6$, $\Delta_i = 6.3$). Comparisons of standardized selection coefficients indicated that blackbirds avoided nesting in low-shrub wetlands. Blackbirds were 4.0–5.9 times less likely to nest in this habitat than in other wetland classes, which were used in proportion to their availability (Table 4).

DISCUSSION

We found that our rapid area searches for breeding Rusty Blackbirds were quite accurate in estimating their abundance and much more effective in sampling the species than previous point-count surveys in our study areas. A single rapid area search for breeding Rusty Blackbirds detected 97% of the nesting pairs actually present and therefore provided a relatively unbiased estimate of abundance. We were surprised by this high detectability because most avian surveys do not detect all birds present and therefore require a correction factor

TABLE 4. Selection of wetland habitats by nesting Rusty Blackbirds in Anchorage, Alaska, 2007–2008, and Tanana Flats, Alaska, 2008. Observed and expected counts of nests compared with log-linear models. Wetland availability based on the sum of wetland classes across all wetland units surveyed for territorial Rusty Blackbirds.

Study area/wetland class	Observed counts	Expected counts	Proportional use (o_i)	Proportional availability (π_i)	Selection function (o_i/π_i)	Standardized selection function (B_i) ^a
Anchorage						
Emergent-vegetation wetland	7	6.1	0.16	0.14	1.14	0.19
Shrub-scrub wetland	20	15.4	0.47	0.36	1.30	0.22
Forested wetland	8	2.5	0.19	0.06	3.16	0.53
Upland	8	18.9	0.19	0.44	0.42	0.07
Tanana Flats						
Sedge meadow	18	17.7	0.33	0.33	1.01	0.26
Low-shrub wetland	3	12.0	0.06	0.22	0.25	0.06
Tall riparian shrub	12	9.8	0.22	0.18	1.22	0.31
Forested wetland	21	14.4	0.39	0.27	1.46	0.37

^aRatios of B_i estimate the relative likelihood of a class of wetland being selected by nesting blackbirds.

to be reliable (Thompson 2002). We believe that detectability was high because we surveyed early in the breeding season (11–23 May) when (1) most females were not yet incubating their eggs (Matsuoka et al. 2010) and were therefore still available for detection and (2) most males were actively singing and guarding their mates. In particular, most of our observations of Rusty Blackbirds during the rapid surveys were of breeding pairs (75% of observations; Table 1), and groups of animals are often more easily detected than solitary individuals (Buckland et al. 2001). We expect that rapid surveys earlier or later in the nesting season would underestimate abundance because they would miss females that had either not arrived or that were incubating eggs or brooding young. In these cases, estimating the detection ratio will be important for providing unbiased estimates of abundance. We did find it important to exclude lone territorial males from the rapid-survey counts as their inclusion overestimated the number of breeding pairs by 17%. Early in the season we sometimes observed lone territorial males flying hundreds of meters across our survey areas (Matsuoka and Shaw, unpubl. data), and such movements may have caused us to double count breeding males (Machtans et al. 2007).

Comparison of our survey results to those of previous surveys in our study areas (Benson 1999, Andres et al. 2001) indicates that detectability is higher during area searches than during point counts. Our area searches revealed Rusty Blackbirds an order of magnitude more abundant than were previously detected by point counts in Anchorage (4 birds among 632 points, Andres et al. 2001) and four times the number of adults detected by point counts on the Tanana Flats (19 birds among 256 points, Benson 1999). These previous surveys took place in June, so we suspect that slightly more Rusty Blackbirds would have been counted if the surveys had been earlier in the season. However, area searches likely yield a detection rate much higher than that of point counts because they sample a greater proportion of the home range, which for the Rusty Blackbird tends to be large because the birds often fly long distances between foraging and nesting sites (Machtans et al. 2007, Powell et al. 2010a). We recommend that researchers consider using area searches and double sampling rather than point counts when surveying for breeding Rusty Blackbirds and possibly other bird species that have large home ranges and low population densities (Brown et al. 2007).

Our estimate of density across our 243-km² Anchorage study site (0.09 pairs km⁻²) is within the range of densities reported in the southeastern portion of the species' breeding range in New England (0.01–0.04 pairs km⁻²; Ellison 1990, Rosenberg and Blancher 2005) and New Brunswick, Nova Scotia, and Prince Edward Island (0.13 pairs km⁻²; Erskine 1992). However, the continued decline and range contraction of the Rusty Blackbird in the southeastern portion of its range (Powell 2008, Greenberg et al. 2011; Maritime Breeding Bird Atlas, unpubl. data) has likely suppressed densities below these levels. Surveys of the southeastern breeding range are

needed to locate the remaining nesting locations and to assess whether these are ecologically distinguishable in terms of land use, landscape position, habitat, food resources, or toxicology from sites where the species has been extirpated. To increase geographic coverage, such surveys could differ from our study by expending more effort on rapid surveys than on intensive nest searches.

We were surprised that densities at Anchorage (2.2 pairs km⁻²) and the Tanana Flats (3.4 pairs km⁻²) were similar when we restricted inference to the immediate area we sampled. We had expected densities to be much lower in Anchorage because in this primarily forested landscape wetlands are rare but on the river floodplain on the Tanana Flats they are abundant. Across the boreal region of Alaska wetlands may therefore support similar densities of nesting pairs with the amount of wetland area regulating population size within a given landscape. Within this context, the vast boreal wetlands along the Yukon River and its major tributaries, such as the Tanana River, are likely important in supporting the global population of the Rusty Blackbird, which Rich et al. (2004) estimated to total 2 million birds across the range.

We found that patterns in habitat selection were more easily detected in Anchorage, where wetlands are discrete and rare, than on the Tanana Flats, where wetlands suitable for breeding appeared to be abundant. We found that the surface area of freshwater ponds, lakes, and shallow water with emergent vegetation was a positive predictor of the numbers of pairs of Rusty Blackbirds nesting in Anchorage. This association with open water has been observed elsewhere, both in the Tanana Valley (Spindler and Kessel 1980) and throughout much of Rusty Blackbird's breeding range (Avery 1995). In New England, the species nests near the shores of rivers and lakes (Kennard 1920, Ellison 1990) and in wetlands with numerous shallow puddles (Powell 2008). In Canada, Machtans et al. (2007) found Rusty Blackbirds breeding near 88% of 24 boreal lakes in the Northwest Territories; DesGranges and Houde (1989) found them near 49% of 131 lakes and ponds in Quebec. Similarly, in both Quebec (LaRue et al. 1995) and Newfoundland (Whitaker and Montevecchi 1997, 1999), Rusty Blackbirds often breed in riparian boreal forests along lakes and rivers but are absent from adjacent upland forests.

Interestingly, we did not find this association on the Tanana Flats where ponds and lakes were rare but surface water was abundant in streams and rivers, graminoid meadows, fens covered by floating mats of vegetation, and a variety of other seasonally flooded types of wetland (Jorgenson et al. 1998b). The number of pairs of blackbirds nesting on the Tanana Flats was instead negatively related to the area of low-shrub wetlands. Similarly, Rusty Blackbirds both avoided low-shrub wetlands for nest sites and nested in other types of wetland in proportion to their availability. On the Tanana Flats the river's floodplain appears to have an abundance of wetlands suitable for breeding, which may have made it more difficult for us to clearly identify the wetlands favored.

Wetlands are clearly important for nesting Rusty Blackbirds. In each study area the species nested in a variety of wetland types; in Anchorage it selected nest sites in forested wetlands and avoided nesting in upland habitats. Throughout its breeding range, the Rusty Blackbird nests facultatively in a variety of conifer and shrub species that are not necessarily restricted to wetlands (Matsuoka et al. 2010, Powell et al. 2010b). In New England, however, Powell et al. (2010b) found that nests located in upland habitats were preyed upon at higher rates, presumably because of higher densities of the red squirrel (*Tamiasciurus hudsonicus*). Thus the Rusty Blackbird's prevailing use of wetlands for nesting may be adaptive. The reasons for the Rusty Blackbird's more specific penchant for nesting near open water, however, is not as clear, and we and other researchers have not found a relationship between the nest's survival and its distance from water (Matsuoka et al. 2010; Powell et al. 2010b). We suspect the species' tie to water is more strongly linked to its specialized requirements for food than for nest sites. We often observed adult Rusty Blackbirds wading in shallow water along shorelines, on floating mats of vegetation, among emergent wetland plants, and in seasonally flooded meadows where they fed on spiders, small fish, and large aquatic invertebrates such as water beetles and larval odonates, the last of which they often fed to their young (Matsuoka and Shaw, unpubl. data). Researchers in New England and Canada have also observed these patterns in foraging behavior (Ellison 1990, Machtans et al. 2007, Powell et al. 2010b). In the lower Mississippi Alluvial Valley the species feeds principally on insects and seeds along shallow water (Greenberg et al. 2011). Thus specialized requirements for feeding may restrict the Rusty Blackbird's distribution during much of its annual cycle, and understanding and providing for these requirements may be key for conserving and managing habitats for this declining species (Greenberg et al. 2011).

Finally, across the boreal region of Alaska, lakes and ponds have been shrinking since 1950. Among the areas sampled, decreases in surface area range from 4 to 31% and decreases in the number of water bodies range from 5 to 54% (Riordan et al. 2006). This reduction is believed to be caused by increases in temperatures and related increases in evapotranspiration and lowering of the water table from thawing permafrost (Yoshikawa and Hinzman 2003, Smith et al. 2005, Riordan et al. 2006). This drying has resulted in changes in limnology and communities of aquatic invertebrates, the latter characterized by declines in biomass of foods important to waterbirds, such as snails, amphipods, and chironomid larvae, which have been supplanted by zooplankton (Corcoran et al. 2009). On the Kenai Peninsula, from 1950 to 1996, invasions of grasses, shrubs, and trees were associated with substantial drying of wetlands. In urban areas of Anchorage, 37% of wetlands have dried and become uplands since 1950 (Klein et al. 2005). Although these patterns of wetland change may not be responsible for the Rusty Blackbird's chronic rangewide decline (Greenberg et al. 2011), our findings indicate that this trend,

if continued, will result in less of breeding Rusty Blackbirds' preferred habitats and may contribute to further declines to this and possibly other birds dependent on boreal wetlands.

ACKNOWLEDGMENTS

We are particularly grateful to A. R. Ajmi, D. Battle, C. D. Gardner, and P. C. McKee of the U.S. Army, H. J. Griese of the U.S. Air Force, and N. DeWitt and A. Ruggles of the Alaska Bird Observatory for providing logistical support for our work on military lands in Alaska. This study was not possible without the hard work and careful data collection by N. C. Dau, H. J. Griese, S. B. Grimes, A. Johnson, L. H. DeCicco, E. W. Lance, R. M. Oates, J. Terenzi, and D. F. Tessler in Anchorage and A. M. Harding, C. Fisher, J. Montgomery, R. J. Rabinovitz, and L. Sweikert on the Tanana Flats. We thank B. A. Andres, J. Bart, C. M. Handel, C. S. Machtans, and S. M. Shaubaug for sharing with us their expertise in designing surveys for birds. We thank R. Greenberg, C. S. Machtans, and an anonymous reviewer for improving an earlier draft of the manuscript. Finally, we thank the members of the International Rusty Blackbird Working Group for instilling in us a rangewide perspective into the research and conservation of this species. This project was generously funded by the Department of Defense's Legacy Resource Management Program, Alaska Bird Observatory, and the U.S. Fish and Wildlife Service's Migratory Bird Management. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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