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## **Assessing the Value of Department of Defense Lands in Alaska to a Declining Species, the Rusty Blackbird**

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Species, the Rusty Blackbird**

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## Table of Contents

<b>Executive Summary</b> .....	2
<b>Introduction</b> .....	3
<b>Chapter 1:</b> Estimating the Abundance of Nesting Rusty Blackbirds in Relation to Wetland Habitats in Alaska .....	5
<b>Chapter 2:</b> Nesting ecology of Rusty Blackbirds in Alaska and Canada .....	23
<b>Chapter 3:</b> Preliminary Estimates of Apparent Adult Survival among Nesting Rusty Blackbirds. ....	50
<b>Chapter 4:</b> Preliminary Results on Concentrations of Environmental Contaminants in the Eggs of Rusty Blackbirds Nesting in Alaska.....	57
<b>Appendix 1:</b> Environmental Mercury Loads may be a Contributing Stressor to Declining Rusty Blackbird Populations.....	60
<b>Appendix 2:</b> Prevalence of Hematozoa among Breeding and Wintering Rusty Blackbirds .....	62

## Executive Summary

In 2007 and 2008 we examined the ecology of Rusty Blackbirds (*Euphagus carolinus*) nesting on military lands in Alaska to contribute to the range-wide understanding of the species' resource requirements and to help identify the factors contributing to the species chronic and range-wide decline. Our study was designed to assess the value of military lands in Alaska to this species within a range-wide perspective and was therefore closely coordinated with other studies throughout the species' global range which includes Alaska, Canada, and the continental U.S. Our surveys and nest monitoring of Rusty Blackbirds clearly showed the importance of military lands in Alaska in terms of providing unfragmented habitats where the species breeds at high relative densities (Chapter 1) and benefits from high rates of reproductive success (Chapter 2). This is unlike the eastern breeding range where Rusty Blackbirds have become quite rare possibly due to low reproductive success in areas recently harvested for timber (Chapter 2) and high exposures to methylmercury which are likely reducing adult and juvenile survival (Appendix 1). Thus, undisturbed wetlands on military lands Alaska may be quite important as centers of production for this declining species.

Our detailed studies of habitat use on military lands in combination with our analysis of nests throughout Alaska and Canada have shown that a preponderant use of small spruce as nest sites across the breeding range is due to selectivity which results in high reproductive success (Chapter 2). Ponds, lakes, and wetlands with emergent vegetation were also important predictors of blackbird abundance (Chapter 1) as were dense willows or dense black spruce near water bodies (Chapter 2). The survey methods that we developed were particularly effective and detected 97% of the nesting pairs breeding on the sites we examined (Chapter 1). These techniques are already being applied elsewhere in the species' breeding range. Our contributions to a range-wide study examining rates of infection by blood parasites has found that Rusty Blackbirds suffer from unexpectedly high rates of infection on the wintering grounds which indicates that the species' immune system may be lowered due to stressors encountered during the non-breeding season (Appendix 2).

Although Rusty Blackbirds populations on military lands in Alaska appear be healthy compared to populations elsewhere, military lands are not without their causes for concerns. Lakes and ponds across boreal Alaska have been shrinking in size as a result of climate warming; if this pattern continues it will result in losses of breeding habitats for the species (Chapter 1). The average levels of blood mercury in adult Rusty Blackbirds were 3-times lower in Alaska than in New England and the Maritime Provinces. However, some birds nesting on the Eagle River Flats and the Tanana Flats had levels that approached those in the eastern range (Appendix 1). Similarly, levels of mercury and strontium in eggs collected on military lands approached levels of concern, although other metals and persistent organic contaminants did not (Chapter 4). Coal-fired energy production in China is increasing at alarming rates and the prevailing winds carry such pollution from Asian to North America where it makes first landfall in Alaska. Thus mercury levels in Rusty Blackbirds should be monitored periodically in Alaska as increases above current levels will likely accelerate declines. Finally, our preliminary results indicated that adult survival was variable from 2007–2009 with survival low in 2008 and at levels equivalent to survival rates of other species of declining blackbirds in the continental U.S. Thus more information is needed to determine whether Rusty Blackbirds on military lands in Alaska

are suffering from chronically low or variable rates of adult survival, both of which have been linked to species declines elsewhere (Chapter 3).

## **Introduction**

The Rusty Blackbird (*Euphagus carolinus*) has suffered one of the steepest declines of any bird species in North America with populations reduced by 90–98% since 1966 (Greenberg and Droege 1999, Greenberg et al. 2010). Because of its decline, this species was recently classified as vulnerable to extinction on the World Conservation Union’s Red List (Bird Life International 2009). However, the Rusty Blackbird remains poorly studied with the cause of its decline unknown. The International Rusty Blackbird Technical Group—which includes representatives from federal (including the Department of Defense [DoD]), university, and non-governmental agencies in the U.S. and Canada—was formed in 2005 to increase awareness of the species’ plight and develop and implement a research and conservation strategy to recover populations. The group has emphasized the need to identify limiting factors and key resource requirements throughout the species’ annual cycle (Greenberg et al. 2010). Such information would help identify the mechanisms driving the decline, help direct conservation towards important areas and habitats, and ultimately help reverse the decline before more costly recovery efforts will be needed.

Military lands in Alaska are particularly important for breeding populations of Rusty Blackbirds because the species has disappeared from many parts of its breeding range where it was once abundant, but still breeds commonly in wetland habitats on military lands in the state (Matsuoka et al. 2008). In this study, we continued the work that we began in 2007 (Matsuoka et al. 2008) to evaluate the value of military installations in Alaska to breeding Rusty Blackbirds in terms of providing breeding habitats associated with high nesting abundance, reproductive success, and adult survival, and low incidence of diseases and contaminants. We conducted our study on Fort Richardson and Elmendorf Air Force Base in Anchorage, and the Tanana Flats Training Area on Fort Wainwright near Fairbanks, Alaska to address the following objectives in the following report chapters:

- (1) Assess survey protocols for estimating the abundance of nesting Rusty Blackbirds relative to wetland habitats (Chapter 1);
- (2) Identify habitats important for supporting nesting and high reproductive success (Chapter 2);
- (3) Identify factors limiting reproductive success such as low egg viability or high rates of nest predation; (Chapter 2);
- (4) Determine if annual adult survival can be examined efficiently on the breeding grounds (Chapter 3);
- (5) Determine whether concentrations of environmental contaminants in eggs are of concern (Chapter 4);
- (6) Determine if exposure rates to blood parasites and environmental mercury are of concern (Appendix).

Each chapter in this report is included in manuscript format to properly acknowledge the chapter authors and to facilitate publication of this work. Chapters 1 and 2 have been submitted for publication in the ornithological journal, the *Condor* as part of a special section entitled, “A

*range-wide perspective into the ecology of a species in decline, the Rusty Blackbird*". Chapters 3 and 4 include the preliminary results of studies that are not yet completed. The Appendix includes abstracts from two range-wide studies that include analyses of blood that we collected from Rusty Blackbirds nesting on military lands. Both of these studies have submitted their findings to the *Condor* special section referenced above. We feel that all the four chapters and the Appendix provide a considerable update to our knowledge of this poorly studied species.

We had also intended to examine the selection of wetland types by foraging Rusty Blackbirds in order to identify important habitats for feeding. We tried to address this objective during field work in 2008 but could not because we found that foraging Rusty Blackbirds were difficult to observe—they often foraged in dense wetland vegetation where they were obscured from our view. We also found during the course of our field work that the GIS coverages of wetland habitats that we had planned to use as the basis for our selection models were insufficient in resolution and accuracy to map the detailed locations of foraging birds relative to wetland types. This was particularly problematic for this species, which often feeds along wetland edges where the accuracy of the GIS data was poorest. However, in 2009 we began to examine the foraging ecology of the species as part of a range-wide study of diet using stable isotopes. This will help us to determine (1) the proportion of the species' diet that is composed of fish, invertebrates, and plants and (2) whether the species feeds primarily on high-trophic predatory invertebrates which would put breeding Rusty Blackbirds at high risk to exposures of biomagnifying contaminants such as mercury (see Chapter 4 and Appendix 1). This component of our study on DoD lands is financed by the Alaska Department of Fish and Game.

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## Chapter 1

### **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 different wetland types. We rapidly surveyed 78 sample units for adult Rusty Blackbirds and intensively searched for nests on a subset of 55 units to determine actual numbers of nests. Rapid survey detected 97% of the 75 nests when we restricted counts to pairs and lone females. The surveys overestimated nest numbers by 17% when we included in the counts lone males, which sometimes took long flights within and between sample units. Nest densities in sampled wetlands averaged 2.2 and 3.4 nests · km<sup>-2</sup> respectively in Anchorage and Tanana Flats; surprisingly similar despite wetlands being rare in Anchorage. An abundance of wetlands made it difficult to identify important breeding habitats 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 emergent vegetation wetlands were positive predictors of nest abundance. Blackbirds also selected forested wetlands and avoided upland habitats for nest sites in this area. An affinity for open water has been noted throughout the Rusty Blackbird's breeding range. Research is needed to understand whether this is due to specialized food requirements and to assess whether this species is vulnerable to widespread wetland drying across boreal Alaska.

## INTRODUCTION

Steep range-wide declines among Rusty Blackbirds (*Euphagus carolinus*; Greenberg and Droege 1999, Greenberg et al. 2010) 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. 2010). 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. Broad-scale avian surveys, such as the roadside North American Breeding Bird Survey, are not well suited for estimating 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. 2010). 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 different wetlands types using a double-sampling technique developed for estimating breeding densities of shorebirds 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 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 most surveys would not encounter enough Rusty Blackbirds to estimate densities using 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 in a range of conditions and to compare patterns of blackbird abundance and habitat selection between a wetland and 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, as well as Fort Richardson and adjacent Elmendorf Air Force Base in Anchorage, Alaska (Anchorage, 61°15'N, 149°41'W). The Tanana Flats included a mosaic of poorly differentiated and large wetland bodies that were flooded annually within the expansive floodplain of the Tanana River. Both upland habitats and ponds and lakes were uncommon in the study area. Surface water was found in wet graminoid meadows, fens dominated by floating mats of wetland vegetation, and slow water tributaries of the Tanana River. Willows (*Salix* spp.) and green alder (*Alnus viridis*) were the common wetland shrubs >1 m in height. Balsam poplar (*Populus balsamifera*) and paper birch (*Betula papyrifera*) were the dominant trees in forested wetlands; there were lesser amounts of black (*Picea mariana*) and white spruce (*P. glauca*). This military training area was not accessible by road.

Wetlands on Anchorage military installations were variable in size, isolated, and dispersed across a primarily upland landscape dominated by boreal forest. Surface water was largely limited to ponds, lakes, and estuaries and nearby areas with shallow water and emergent wetland vegetation. The plant species in Anchorage wetlands were similar to those on the Tanana Flats, but black spruce was more common and willows (>1 m in height) were less common in Anchorage compared to the Tanana Flats (Matsuoka et al. *in review*). All wetlands within Anchorage were accessible by road, foot, or canoe. Plant and bird communities were previously described in detail for Fort Richardson (Jorgenson et al. 1998a, Andres et al. 2001) and for Fort Wainwright (Jorgenson et al. 1998b, Benson 1999).



To determine our sampling allocation, we first obtained digital geo-referenced data from the National Wetlands Inventory for Anchorage (NWI; Cowardin et al. 1979) and from land classifications based on Viereck et al. (1992) that were developed for the Tanana Flats (Jorgenson et al. 1998b). We then used these data to identify wetland bodies, calculate their area, and differentiate wetlands classes. We used different land cover classifications for the two study areas because NWI were the only data that covered the entire Anchorage study area and we found that the land classifications for the Tanana Flats by Jorgenson et al. (1998b) were more accurate than those by the NWI. Due to differences in wetland landscapes and accessibility between the two study areas, 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 500 x 500-m sample units (25 ha) across the study area and selected for surveys the 45 units (total area of 11.25 km<sup>2</sup>; Fig. 1) 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 wetland bodies as potential sample units. We selected for sampling all wetland bodies 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). This 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 resulted in the selection of 33 sample units ranging from 1.1–139.2 ha in area ( $\bar{x} = 29.4 \pm 6.1$  ha) and totaled 9.67 km<sup>2</sup> (Fig. 2). 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 wetland size 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 nesting pairs of Rusty Blackbirds in Anchorage in 2007 and 2008 and on the Tanana Flats in 2008. This included two sets of surveys; (1) rapid surveys of sample units to populate the raw count data for abundance and (2) nest searches on a subset of these sample units to determine actual numbers of nesting pairs (actual pairs). In Anchorage, we conducted rapid surveys and searched for nests on all 33 sample units in 2007. In 2008 we conducted rapid surveys in Anchorage on a subset of 23 sample units ( $\bar{x} = 37.0 \pm 7.9$  ha, total area sampled = 852 ha) and searched for nests on all of the sample units on which we detected territorial adults during our rapid surveys in either 2007 or 2008. We excluded from sampling 1) seven sample units <4 ha in area because they did not host nesting blackbirds in 2007 and 2) three sample units in areas where military activities restricted regular access.

On the Tanana Flats we conducted a single rapid survey on 45 sample units and conducted nest searches on a subsample of 22 units in 2008. The latter included the 11 sample units with the

highest counts of blackbird pairs during the rapid surveys and a random selection of 11 additional samples units that were near these. In 2007, we searched for nests but did not rapidly survey for blackbirds on 13 of these sample units on the Tanana Flats. We did not include these data in our analyses of abundance using double sampling but did include the locations of the nests from 2007 in our analyses of nest-sites selection (see STATISTICAL ANALYSES).

We conducted our rapid surveys from 11–23 May and between 0600–1300 h. This spanned the period from pair formation to early incubation (Matsuoka et al. *in review*), 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 did not vary over the morning (P. Blancher, *unpublished data*; C. S. Machtans, *unpublished data*). We conducted rapid surveys at a rate of  $10 \text{ ha} \cdot \text{h}^{-1}$  during which we walked a path passing within approximately 100 m of all points in a unit and mapped on aerial photos the gender, movements, and behaviors of each adult Rusty Blackbirds that we encountered. We took special care to distinguish our observations of pairs versus lone individuals and to map our simultaneous observations of two or more birds to help separate neighboring pairs after they had moved (Ralph et al. 1993). In Anchorage, we also surveyed the shorelines of the larger lakes by canoe when possible. At the end of each survey we classified bird detections by gender and pairing status and then tallied the total number of observed pairs, lone territorial males, and lone females on the survey unit (Bart and Ernst 2002). We excluded from the tally any males that did not exhibit territorial behavior, any adults only observed 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 latter birds in order to minimize the probability of double counting individuals among nearby survey units (Machtans et al. 2007).

We conducted nest searches on a subset of sample units from 15 May–5 June. In Anchorage, we conducted one or three nest-searching visits: one nest-searching visit when we did not detect adult blackbirds on either the rapid survey or the initial nest-searching visit; three nest-searching visits when we detected adults on either the rapid survey or the initial nest-searching visit. On the Tanana Flats we conducted three nest searches on each selected unit. During each visit we concentrated our searches to wet meadows and to 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 on our sample units when we visited nests to monitor their survival (Matsuoka et al. *in review*). For each sample unit we determined the actual number of nesting pairs by summing the number of nests and the number of territorial pairs on the unit for which we could not find their nests. We did not include in these tallies those nests that we suspected to be renesting attempts based on their chronology and location relative to known nest failures.

## STATISTICAL ANALYSES

We first evaluated the accuracy of the rapid surveys by examining the data from the subset of sample units on 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 different 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 minimized bias in detectability. We then used the combination of counts that minimized bias and further evaluated the accuracy of the rapid surveys by calculating the proportion of sample units that the survey correctly classified as used versus not used by nesting pairs of Rusty Blackbirds.

We then corrected our rapid survey counts for  $\hat{p}$  and estimated the nesting 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 km<sup>2</sup> 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 both for the immediate wetlands surveyed (9.67 km<sup>2</sup>) and for the entire study area (243 km<sup>2</sup>) in Anchorage.

We used Poisson regression to assess whether the availability of each wetlands class was a strong predictor of the number of blackbird pairs nesting in a sample unit. The wetland classes that we evaluated for the Anchorage study area were the area (ha) of ponds and lakes, emergent vegetation wetlands, scrub-shrub wetlands, forested wetlands, and upland habitats. We used the maximum number of actual pairs on each sample unit in Anchorage (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 among sample units (Jones et al. 2002). The wetland classes that we evaluated for the Tanana Flats 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 counts and estimated pairs as our measure of breeding abundance. We used the actual counts for the 22 survey units that we intensively searched for nests. We used the count of observed pairs plus lone females for units that we only rapidly surveyed because we found this 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 among models in each study area using Akaike's information criterion adjusted for small sample sizes ( $AIC_c$ ) and rescaled as  $AIC_c$  differences ( $\Delta_i$ ) and model probabilities ( $w_i$ ). We summed  $w_i$  among models sharing a common explanatory variable to assess the overall evidence that the variable was associated with breeding abundance ( $\sum w_i$ , Burnham and Anderson 2002).

We examined the selection of habitats for nest sites separately for each study area by comparing the frequencies that blackbirds used particular wetland classes for nest sites versus the availability of these wetland classes 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 ha surveyed of each wetland class), which allowed the number of samples to vary between use and available categories. We then compared the  $AIC_c$  values between the null model to one that added the interaction, use \* 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 computed and compared standardized selection functions using the methods of Manly et al. (1993).

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. We sampled 10 of these sample units in Anchorage 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 for which we could not find their nests (Table 1). We found that the rapid survey best estimated the actual number of nesting pairs when we restricted the count to the number of pairs plus the number of lone females (Table 1). Using 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, the survey underestimated abundance in Anchorage ( $81 \pm 11\%$  of actual pairs detected) and for the study sites combined ( $88 \pm 9\%$ ), but was 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 over the area sampled and the total number of actual nests in Anchorage in 2007 was  $2.2 \pm 1.0$  pairs  $\text{km}^{-2}$  and  $21.0 \pm 9.6$  nests, respectively ( $n = 33$  survey units). Extrapolated across the military lands in Anchorage, density averaged  $0.09 \pm 0.04$  pairs  $\text{km}^{-2}$ . When we restricted our analysis of the Anchorage data to the survey units sampled in both 2007 and 2008, density averaged  $2.5 \pm 1.1$  pairs  $\text{km}^{-2}$  ( $n = 23$  units), which was 73% of the average densities of  $3.4 \pm 0.9$  pairs  $\text{km}^{-2}$  ( $n = 45$  units) on the Tanana Flats in 2008. We estimated that there were a total of  $38.7 \pm 9.8$  pairs of Rusty Blackbirds nesting on the surveyed portion of the Tanana Flats in 2008. Densities of nesting pairs on individual survey units with blackbirds

varied from 2.7–24.2 pairs km<sup>-2</sup> in Anchorage ( $n = 8$  survey units) and 4–12 pairs km<sup>-2</sup> on the Tanana Flats ( $n = 25$  survey units).

*Predictive models of nesting abundance.* In Anchorage, a Poisson regression that included lakes and ponds and emergent vegetation wetlands 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 on a unit increased with increases in the area of lakes, ponds, and emergent vegetation (Table 2a). 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 wetlands than survey units without nesting pairs (Table 3a). 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 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 ( $\sum w_i = 1.00$ ). We found less support for models with emergent vegetation wetlands ( $\sum w_i = 0.47$ ), upland habitat, shrub wetlands, or forested wetlands ( $\sum w_i \leq 0.27$ ; Table 3a).

On the Tanana Flats, a Poisson regression that included low shrub wetlands best predicted the count of nesting pairs with the count decreasing with increases in the area of low shrub wetlands in a sample unit ( $L = -40.0$ ,  $n = 45$  survey units,  $K = 3$ ,  $AIC_c = 86.6$ ,  $w_i = 0.35$ ; Table 2b). Survey units with nesting pairs had 41% of the mean area of low shrub wetlands found on survey units without nesting blackbirds (Table 3b). 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 ( $\sum w_i = 0.89$ ). We found far less support for models with emergent vegetation wetlands, forested wetlands, rivers, or upland habitats ( $\sum w_i \leq 0.22$ ; Table 3b).

*Selection of wetlands 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 Blackbirds nests in shrub-scrub wetlands; we found similar numbers of nests in the other wetlands classes (Table 4a). 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 Rusty Blackbirds in Anchorage were 7.4 times more likely to select nest sites in forested wetlands than upland habitats, which they tended to avoid. Nests were located in emergent and shrub-scrub wetlands in proportion to availability (Table 4a).

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 4b). 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 low shrub wetlands for nest sites. Blackbirds were 4.0–5.9 times less likely to nest in this habitat than other wetland classes which were used in proportion to their availability (Table 4b).

## DISCUSSION

We found that our rapid area searches for Rusty Blackbirds were quite accurate in estimating breeding abundance and much more effective in sampling the species than previous point counts surveys in our study areas. A single rapid area search for breeding Rusty Blackbirds detected 97% of the actual nesting pairs 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 of birds present and therefore require a correction factor to be reliable (Thompson 2002). We believe that detectability was high because we conducted our surveys early in the breeding season (11–23 May) when (1) most females were not yet incubating their eggs (Matsuoka et al. *in review*) 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 conducted 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 censure lone territorial males from the rapid survey counts as their inclusion overestimated the number of breeding pairs by 17%. We sometimes observed lone territorial males flying hundreds of meters across our survey areas early in the season (Matsuoka and Shaw, *unpublished data*) and such movements may have caused us to double count breeding males within or among our survey sites (Machtans et al. 2007).

Comparisons of our survey results to those from previous surveys in our study areas (Benson 1999, Andres et al. 2001) indicated that detectability is higher during area searches than during point count surveys. Our area searches detected an order of magnitude more Rusty Blackbirds than were previously detected on point count surveys conducted in Anchorage (4 birds among 632 points, Andres et al. 2001) and four times the number of adults counted on point counts conducted across the Tanana Flats (19 birds among 256 points, Benson 1999). Area searches likely have a higher detection rate than point counts because they sample a greater proportion of the home range, which tend to be large for Rusty Blackbirds because they often fly long distances between foraging and nesting sites (Machtans et al. 2007, Powell et al. *in review a*). We recommend that researchers consider using area searches and double sampling in favor of point counts when surveying for breeding Rusty Blackbirds and possibly other bird species that have large home ranges and breed at low densities (Brown et al. 2007).

Our estimate of nesting densities across our 243-km<sup>2</sup> Anchorage study site (0.09 pairs · km<sup>-2</sup>) was within the range of densities reported in the southeastern portion of the species' breeding range in New England (0.01–0.04 pairs · km<sup>-2</sup>; Ellison 1990, Rosenberg and Blancher 2005) and New Brunswick, Nova Scotia, and Prince Edwards Island (0.13 pairs · km<sup>-2</sup>; Erskine 1992). However, the continued decline and range contraction of Rusty Blackbirds in the southeastern range (Greenberg et al. 2010) has likely resulted in breeding densities below these levels. Surveys are needed in the southeastern breeding range 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.

We were surprised that blackbird densities were similar between Anchorage (2.2 pairs · km<sup>-2</sup>) and the Tanana Flats (3.4 pairs · km<sup>-2</sup>) when we restricted inference to the immediate areas that we sampled. We had expected densities to be much lower in Anchorage because wetlands were rare across this primarily forested landscape and abundant across the river floodplain on the Tanana Flats. Wetlands across the boreal region of Alaska 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 the Tanana River, are likely globally important in supporting large numbers of breeding Rusty Blackbirds which are estimated to total 2 million birds across their range (Rich et al. 2004).

We found that patterns in habitat selection were more easily detected in Anchorage, where wetlands were discrete and rare, than the Tanana Flats, where suitable wetlands for breeding appeared to be abundant. We found that the surface area of freshwater ponds, lakes, and shallow water areas with emergent vegetation were positive predictors of the numbers of Rusty Blackbird pairs nesting among our survey units in Anchorage. This association with open water has been observed elsewhere both in the Tanana Valley, Alaska (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, Rusty Blackbirds were found breeding near 88% of 24 boreal lakes in the Northwest Territories (Machtans et al. 2007) and 49% of 131 lakes and ponds in Quebec (DesGranges and Houde 1989). Similarly, Rusty Blackbirds often bred in riparian boreal forests along lakes and rivers but were absent from adjacent upland forests both in Quebec (LaRue et al. 1995) and Newfoundland (Whitaker and Montevecchi 1997, 1999).

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 wetland types (Jorgenson et al. 1998*b*). The number of nesting pairs of blackbirds 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 wetland types in proportion to their availability. The river floodplain of the Tanana Flats appears to have an abundance of suitable wetlands for breeding which may have made it more difficult for us to clearly identify favored wetlands for breeding.

Wetlands were clearly important for nesting Rusty Blackbirds with the species placing nests in a variety of wetland types in both of our study areas and selecting nest sites in forested wetlands and avoiding nest sites in upland habitats in Anchorage. Throughout their breeding range, Rusty Blackbirds nest in a variety of facultative conifer and shrub species that are not necessarily restricted to wetlands (Matsuoka et al. *in review*, Powell et al. *in review b*). However, nests located in upland habitats were preyed upon at higher rates in New England, presumably due to higher densities of red squirrels (*Tamiasciurus hudsonicus*; Powell et al. *in review b*). Thus, the generalized 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 nest survival and the distance of nests from water (Matsuoka et al. *in review*, Powell et al. *in review b*). We suspect the species' tie to water is more strongly linked to its specialized resource requirements for food rather than 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 later of which were often fed to their young (Matsuoka and Shaw, *unpublished data*). Researchers in New England and Canada have also observed these patterns in foraging behavior (Ellison 1990, Machtans et al. 2007, Powell et al. *in review b*); researchers also report that the species feeds principally on insects and seeds along shallow water areas in the lower Mississippi Alluvial Valley (Greenberg et al. 2010). Thus, specialized feeding requirements may restrict the distribution of Rusty Blackbirds during much of their annual cycle and understanding and providing for these requirements may be key for conserving and managing habitats for this declining species (Greenberg et al. 2010).

Finally, lakes and ponds across the boreal region of Alaska have been shrinking in size since 1950 with decreases in surface area ranging from 4–31% and decreases in the number of water bodies ranging from 5–54% among the areas sampled (Riordan et al. 2006). This is believed to be caused by increases in temperatures and related increases in evapotranspiration and lowering of the water table from permafrost thawing (Yoshikawa and Hinzman 2003, Smith et al. 2005, Riordan et al. 2006). This pattern in drying has resulted in changes in limnology and aquatic invertebrate communities; the latter characterized by declines in biomass of important waterbird foods, such as snails, amphipods, and chironomid larvae, which have been supplanted by zooplankton (Corcoran et al. 2009). In other boreal wetlands, invasions of facultative grasses, shrubs, and trees were associated with substantial wetland drying on the Kenai Peninsula from 1950–1996. In Anchorage, 37% of wetlands in urban areas 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 range-wide decline (Greenberg et al. 2010), our findings indicated that these drying trends, if continued, will result in less preferred habitats for breeding Rusty Blackbirds and may contribute to further declines to this and possibly other obligate boreal wetland birds.

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Figure 1. Locations of 45 sampling units that we rapidly surveyed for breeding Rusty Blackbirds on the Tanana Flats Training Area of Fort Wainwright, Alaska. Sample units are shaded  to denote where rapid surveys detected territorial Rusty Blackbirds in 2008. Sample units are shaded  to denote where rapid surveys did not detect territorial birds in 2008. Circles denote the location of nests found in 2007 (yellow) and 2008 (red).

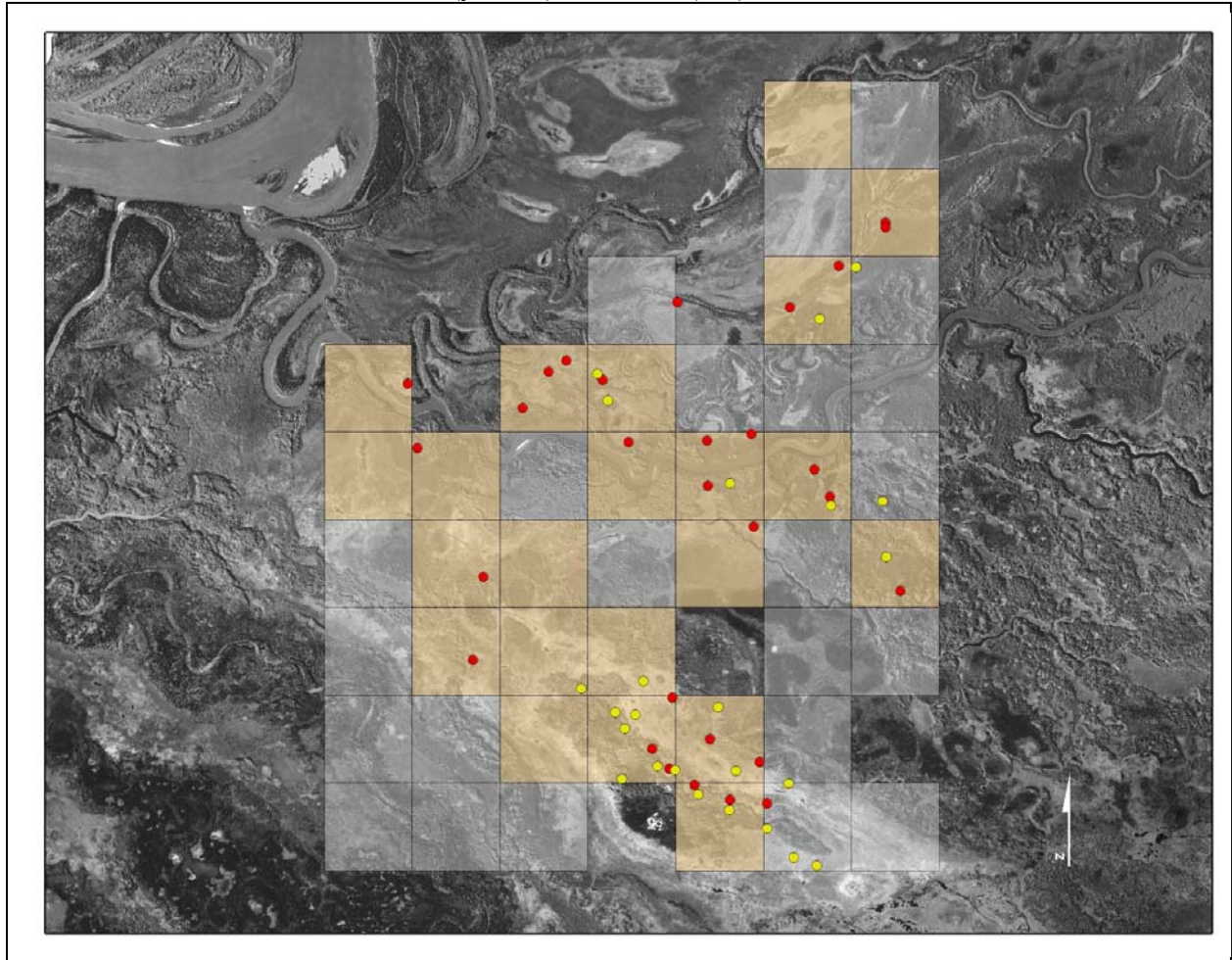


Figure 2. Locations of sampling units (outlined in grey) that we rapidly surveyed for breeding Rusty Blackbirds on Elmendorf Air Force Base ( $n = 16$  units) and Fort Richardson ( $n = 17$  units), Alaska 2007–2008. Circles denote the locations of nests found and monitored in 2007 (yellow) and 2008 (red). Strong predictors of nest abundance included the area of water of ponds and lakes (dark blue) and emergent wetland vegetation (green).

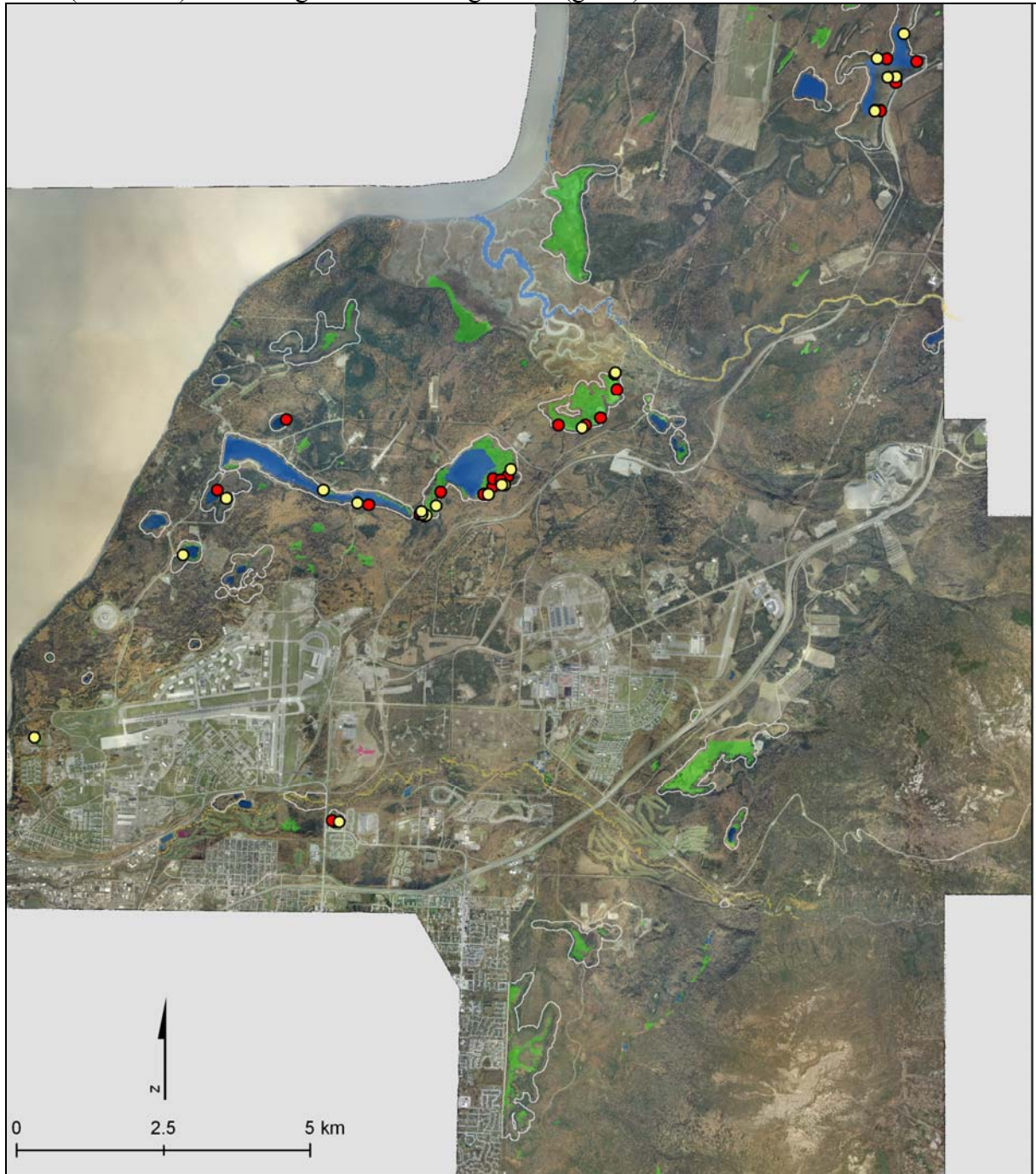


Table 1. Comparisons of detection ratios ( $\hat{p} \pm SE$ ) of nesting pairs of Rusty Blackbirds counted during rapid surveys of nest-searching plots in Anchorage and the Tanana Flats, Alaska. The actual count is the sum of first nests found ( $n = 70$ ) and territorial pairs ( $n = 5$ ) with territory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

Units of observation <sup>1</sup>	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 & 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		

<sup>1</sup>During our rapid surveys most of our observations were of pairs where males were closely guarding females ( $n = 66$  detections); we detected smaller number of lone females ( $n = 7$ ) and lone territorial males ( $n = 15$ ).

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

Variable	Estimate	SE	<i>P</i>
a) 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
b) Tanana Flats			
Intercept	0.26	0.19	0.18
Low shrub wetland	-0.10	0.04	0.01

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

Study Area / Wetland type <sup>1</sup>	Used	Not used	$\sum w_i$ <sup>2</sup>
a) 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
b) 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

<sup>1</sup> In Anchorage we used covariates based 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).

<sup>2</sup> We compared the relative importance of wetland types as predictors of the number of breeding pairs by summing model weights ( $\sum w_i$ ) among all univariate and bivariate Poisson regressions calculate separately for each study area.

Table 4. Selection of wetland habitats by nesting Rusty Blackbirds in a) Anchorage, Alaska, 2007–2008 and b) Tanana Flats, Alaska, 2008. Observed and expected counts of nests were compared using log-linear models. Wetland availability was 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 ( $\pi_i$ )	Selection function ( $o_i/\pi_i$ )	Standardized selection function ( $B_i$ ) <sup>1</sup>
a) Anchorage						
Emergent vegetation wetland	7	6.1	0.16	0.14	1.14	0.19
Scrub-shrub 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
b) 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

<sup>1</sup> Ratios of  $B_i$  estimate the relative likelihood of wetlands classes being selected by nesting blackbirds.



## Chapter 2

### **Nesting ecology of Rusty Blackbirds in Alaska with Reference to Nest Records from Canada**

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*Abstract.* We examined the nesting ecology of Rusty Blackbirds (*Euphagus carolinus*) from 162 nests monitored for nest survival in Alaska and 252 incidental records from Alaska and Canada to identify important habitats for nesting and to test whether low rates of nest success were contributing to populations declines in Alaska. In coastal Alaska and throughout Canada, nests were primarily in conifers (85% of 212 nests). All conifer nests in Alaska and 80% in Canada were placed in spruce (*Picea* spp.) with use of black spruce (*P. mariana*) particularly widespread. Use of small spruces in Alaska was selective and resulted in high reproductive success—nest survival increased with densities of small black spruce and nest success was higher for nests in spruce (79%) than in deciduous vegetation (52%). Nest survival declined for nests in tall spruce, possibly from predation by red squirrels (*Tamiasciurus hudsonicus*). Rusty Blackbirds nested near water in interior ( $\bar{x} = 8$  m) and south-central Alaska ( $\bar{x} = 30$  m) and small spruce near water appeared to be important over much of the species' range. However, most nests in interior Alaska were in willows (78%) which dominated the vegetation near water. Nest success averaged 56% in Alaska, similar to rates over the same period in New England, but higher than other North American blackbirds (30–39%). Studies are needed to verify whether nest survival is also high in Canada and to understand where and why deficits in adult or juvenile survival may be limiting population growth.

*Key words:* Alaska, Canada, *Euphagus carolinus*, nesting ecology, nest-site selection, nest success, nest survival, Rusty Blackbird.

## INTRODUCTION

The Rusty Blackbird (*Euphagus carolinus*) breeds across North America's vast boreal forest where it is often associated with forested wetlands and open freshwater bodies (Avery et al. 1995, Greenberg et al. 2010, Matsuoka et al. *in review*). Ornithologists had often described the

Rusty Blackbird as common or abundant up until the early 20<sup>th</sup> century—since then it has suffered one of the steepest range-wide declines of any bird species in North America (Link and Sauer 1996, Greenberg and Droege 1999, Niven et al. 2005). The causes of the decline remain unknown (Greenberg et al. 2010). Despite its broad range, steep decline, and high conservation concern (Rich et al. 2004, Greenberg et al. 2010), the nesting ecology of the Rusty Blackbird is known only from a small number of nests placed primarily in small spruce (*Picea* spp.) and balsam fir (*Abies balsamea*) in the extreme southeastern portion of the species' breeding range in New England (Kennard 1920, Ellison 1990, Powell et al. *in review*). Information on nest survival in New England has only just become available (Powell et al. *in review*) and even basic information such as the length of the incubation and nestling periods remain unconfirmed (Kennard 1920, Avery 1995). Thus, a much broader assessment of the species' nesting ecology is needed to document basic attributes of the species' life history, identify important habitats for nesting, and evaluate whether chronically low reproductive success is contributing to the species' decline (Greenberg et al. 2010).

In this study we evaluated the nesting ecology of Rusty Blackbirds in Alaska by examining data from 162 nests found across six study areas from 2006–2008. We augment this with information from 22 nests found at other locations in Alaska from 1995–2008 and data from 230 nests found across Canada from 1887–2008 and included as part of the national nest-records program (Bird Studies Canada 2009). Specifically, we first analyze data from these nests to describe the general nesting chronology of the species and to test for spatial variation in clutch size, vegetation used for nest sites, and nest heights. Secondly, we examine data collected from the six study areas in Alaska to test whether clutch initiations and daily nest survival varied spatially or temporally. We then analyze data from the subset of nests monitored on military sites in Alaska to identify habitat features associated with nest-site selection and to test whether daily nest survival varied with habitat features. Finally, we discuss our findings from Alaska and Canada in relation to those from New England (Kennard 1920, Ellison 1990, Powell et al. *in review*) to provide a range-wide perspective to the nesting ecology of the least studied and northernmost breeding of North America's blackbirds (Avery 1995).

## METHODS

### STUDY AREA

We obtained data on nesting Rusty Blackbirds from across the species' breeding range outside of New England. This included data from the boreal forest region of Alaska and Canada as well as a limited number of nest records from the temperate rainforest region of Alaska. From Canada, we obtained data on 230 nests from Project NestWatch (Bird Studies Canada 2009), which included nest records of Rusty Blackbirds from all Canadian provinces and territories except Nunavut. This included nests from the Yukon Territories (YT,  $n = 14$  nests), British Columbia (BC,  $n = 44$ ), Northwest Territory (NT,  $n = 7$ ), Alberta (AB,  $n = 7$ ), Saskatchewan (SK,  $n = 5$ ), Manitoba (MB,  $n = 3$ ), Ontario (ON,  $n = 52$ ), Quebec (QC,  $n = 34$ ), Newfoundland (NL,  $n = 7$ ), Nova Scotia (NS,  $n = 38$ ), and New Brunswick (NB,  $n = 19$ ). In Alaska, most of the data ( $n = 162$  nests) were from six study areas collectively surveyed for nests from 2006–2008 in interior and south-central regions of the state. Other data came from incidental observations of nests from 1995–2008 in interior ( $n = 20$  nests) and southeast Alaska ( $n = 2$  nests; Fig. 1).

In interior Alaska, blackbirds were examined at four study locations that were within the expansive floodplain of the Yukon River and its major tributaries and included (west to east) the Innoko National Wildlife Refuge (Innoko; 63° 34'N, 158° 16'W; R. M. Corcoran data), Fairbanks (64° 52'N, 147° 45'W; D. Shaw, 2006 data; N. A. Rojek, 2008 data), the Tanana Flats Training Area of the U.S. Army's Fort Wainwright (Tanana Flats; 64° 45'N, 147° 45'W; D. Shaw data), and Tetlin National Wildlife Refuge (Tetlin; 62° 39' N, 141° 3'W; D. Shaw data; Fig. 1). These study areas were generally located in complex mosaics of poorly differentiated wetlands with lesser amounts of upland habitats. Willow (*Salix* spp.) and alder (*Alnus* spp.) were the common wetland shrubs > 1 m in height; balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*), black spruce (*Picea mariana*), and white spruce (*P. glauca*) were the dominant trees in forested wetlands. We accessed the study sites in Innoko and the Tanana Flats by motor boat and searched for nests in wetlands along 22 km of Hather Creek (Innoko) and 11.25 km<sup>2</sup> of floodplain adjacent to the Tanana River (Tanana Flats; Matsuoka et al. *in review*). Study sites in Fairbanks and Tetlin were accessed by road and included wetlands with open water bodies on the perimeter of the city of Fairbanks and two lakes and their adjacent forested and shrub wetlands near the Alaska Highway (Tetlin).

In south-central Alaska, study areas included boreal wetlands within Elmendorf Air Force Base and adjacent Fort Richardson near Anchorage (Anchorage; 61°15'N, 149°41'W; S. M. Matsuoka data) and a large wetlands complex in the temperate rainforest zone along the upper Copper River Delta (Copper River; 60° 23' N, 145° 18'N; P. M. Meyers data; Fig. 1). The study area in Anchorage was located in a primarily upland landscape. Wetlands of various sizes were generally isolated and dispersed; we searched for nests in all wetlands that were seasonally or permanently flooded ( $n = 33$ ) and their adjacent 50-m of upland habitats (Matsuoka et al. *in review*). The dominant trees and shrubs within wetlands in Anchorage were similar to those in interior Alaska except that willows were uncommon. The Copper River study area was located in a large network of freshwater sloughs and wetlands where woody plants >1 m in height grew on the banks of sloughs, were dominated by willow and alder, and had fewer young Sitka spruce (*P. sitchensis*). Plant communities in this area were undergoing rapid succession as a result of substantial uplifting from the Good Friday earthquake of 1964 (Stover and Coffman 1993).

## FIELD SAMPLING

All nests from Canada and a small number from Alaska were found incidental to other field work. Most of these nests were visited one or two times and thus did not provide information to assess nest survival. Each nest record was accompanied by a date and typically included the number of eggs or nestlings, the plant species used for nesting, and the height of the nest (m). In Alaska, the dates of field work varied among the six study sites where we intensively searched for and monitored nests: Anchorage (10 May–5 July 2007 and 2008), Copper River (25 May–21 June 2006), Fairbanks (13 May–28 June 2006 and 2008), Innoko (3–18 June 2006), Tanana Flats (10 May–5 July 2007 and 2008), Tetlin (19 May to 19 June 2008). In each study area, field observers systematically surveyed wetland habitats for territorial Rusty Blackbirds either by foot or from the water by canoe (Anchorage and Tetlin), kayak (Copper River), or motor boat (Innoko). We searched blackbird territories for nests by observing adults from a distance and following them back to their nests as they carried nest materials or returned to incubate their eggs or feed their mates or young. When we found nests during incubation in Anchorage and Copper

River, we estimated the stage of incubation by candling the eggs and comparing the observed stage of embryo development to known stages of development in Red-winged Blackbird eggs (Figure 2 in Lokemoen and Koford 1996). When we found nests with nestlings in all study areas, we estimated their age based on their size. We monitored each nest every 2–7 days to determine survival, egg laying intervals, and lengths of the incubation and nestling periods. When we did not observe activity we inspected nests to verify failure or fledging (Martin and Geuple 1993).

We often monitored activity at nests from a distance with binoculars but when possible we visually examined the contents of nests, either directly or with the aid of a mirror mounted on a telescoping pole, once during laying to determine date of clutch initiation; once during incubation to determine final clutch size; on the estimated hatch date to estimate the incubation period and the number of eggs hatched; and four days before estimated fledging to band, weigh, and measure nestlings, and determine the number prior to fledge. Thereafter, we checked nests from a distance until we verified fledging or failure. We captured a subset of adults in mist nests (2.6 m x 6.0 m or 2.6 m x 12.0 m; 36-mm mesh) placed near their nests and banded each bird with a unique combination of one USGS aluminum band and three colored-leg bands (Anchorage, Innoko, and Tanana Flats). We considered nests to have been successful when we observed adults feeding newly fledged young within 100 m of the nest. We considered nests to have failed from predation when nest contents disappeared before they had adequate time to fledge, when we found an empty nest with the materials pulled apart, or when we found egg-shell fragments below an empty nest. We considered nests to have been abandoned due to our activities when we found a clutch of cold eggs on the visit after we banded the adults. During all nest visits we searched for additional nests when new pairs were encountered. Following each nest failure, we searched the associated territory for renesting and monitored such nests as described above.

There were notable exceptions to these protocols. In Anchorage and Tanana Flats, 2008, we inserted iButtons (model DS1992L)—temperature data loggers enclosed in a 16-mm stainless steel case—into a subset of nests and onto nearby trees to record nest and ambient temperatures at 10-min intervals and thereby provide precise dates for fledging and failures which we assumed occurred when nest temperatures dropped and remained at ambient levels (Hartman and Oring 2006). In Anchorage, 2008, we could not visually inspect the contents of two nests in the tree canopy (> 4 m above the ground). We therefore determined activity at these nests by repeatedly observing adults at nests using binoculars or a spotting scope. We assumed these nests to be in the incubation stage if we observed a female sitting continuously on the nest for >20 min and if we repeatedly observed adults approaching an unattended nest with no food in their bills. We assumed nests to contain nestlings if we observed adults carrying food to an unattended nest and subsequently leaving the nest with an empty bill or fecal sac (Martin and Geuple 1993, Martin et al. 1997).

Following each nesting attempt in Alaska, we recorded the nest location in a global position system (GPS) and sampled the habitat of the nest-microsite for variables that included the plant species used for nesting, height of the nest above the ground or water (m), and the state of morbidity (alive or dead) of the tree or shrub used for nesting. In Anchorage and the Tanana Flats, we also measured the diameter-at-breast height (dbh [cm] at 1.37 m) and the height (m) of

tree or shrubs used for nesting. When more than one tree or shrub stem supported the nest, we measured the dbh of each stem and the height (m) of the tallest supporting stem. At these two sites we also estimated the concealment of the nest by foliage from 1 m above and 1 m from the side at nest height from each of the cardinal directions in quarterly increments (0–25%, 26–50%, 51–75%, 76–100% concealment); we used the minimum of the 5 nest-cover scores for each nest as a conservative index of its vulnerability to potential predators. We used a GIS to measure the distance from each nest to the nearest neighboring nest (m) in Anchorage and Tanana Flats where we thoroughly searched the sampled areas for nests in order to estimate nest densities (Matsuoka et al. *in review*). In Anchorage, Tanana Flats, and Tetlin we measured the dimensions of nests and noted the materials used in their construction.

In Anchorage and the Tanana Flats, we also measured vegetation within a 20 x 20-m plot centered on each nest (nest area), and within a 20 x 20-m plot located at a random distance (40–60 m) and cardinal direction from each nest but not in open water. We chose the 20 x 20-m plot size because it sampled a similar area as standard passerine nesting studies (James and Shugart 1970, Martin et al. 1997); we chose the square dimension because of the relative ease compared to circular plots in determining whether trees and shrubs near the plot boundary were within the sample area (Husch et al. 2003). Within each nesting area and plot of available habitat we counted the number of stems of standing trees and shrubs by species, dbh class (2.5–8 cm, >8 cm) and state of morbidity (live or dead). On the Tanana Flats we restricted our stem counts to within a 10 x 10-m plot when we encountered dense willows or alders. We multiplied stem counts within the 10 x 10-m plots by 4 to standardize them to the 0.04 ha area sampled within the 20 x 20-m plots. At 39 intercept points systematically distributed at 1.5-m intervals along three 20-m transects spaced 6 m apart, we measured canopy cover by looking directly overhead through a sighting tube to determine the proportion of points with foliage above 3 m (James and Shugart 1970, Ganey and Block 1994). We estimated water cover as the proportion of the intercept points landing on surface water. Although several different observers performed vegetation sampling, we trained them in techniques of vegetation measurement prior to sampling in order to minimize observer variation in measurement and ocular estimation of cover (Block et al. 1987).

## STATISTICAL ANALYSES

We analyzed different subsets of the Rusty Blackbirds nest data to address different aspects of the nesting ecology of the species. At the largest scale we evaluated all nests from Alaska and Canada to describe the species' basic nesting ecology and to determine whether clutch sizes or substrates used for nesting varied spatially. We examined the data from nests in Alaska to test whether clutch initiation dates, clutch sizes, and nest survival varied temporally and spatially. Finally, we analyzed data from our intensive studies on military lands in Alaska to evaluate nest-site selection and to test whether nest survival varied with habitat.

*Nesting chronology and clutch size.* We first screened all nest records from Alaska and Canada and examined the subset of nests with multiple observations during nest building, egg laying, incubation, or the nestling period to describe the timing and lengths of each period. We estimated the laying interval by examining data from nests with more than one observation during laying to determine whether the number of eggs and number of days between

observations were equivalent. We determined when incubation began relative to clutch completion by examining our observation of females at nests during laying in Alaska and by comparing nest temperatures to ambient temperatures for three nests in Anchorage fitted with iButtons before clutch completion.

We estimated clutch initiation dates for 138 nests in Alaska that we either observed during egg laying or had multiple observations of the final clutch size and had accurate information on the date of hatch or the date of fledging. We did so by backdating based on our observations of the laying interval, the clutch size, the modal number of days from clutch completion to the beginning of hatch, and the modal number of days from the beginning of hatch to fledging. We then used analysis of variance (ANOVA) and developed eight models of clutch initiation date that included the intercept only; the univariate effects of year, location, and region; and the bivariate and full-factorial effects of location plus year and location plus region. We compared the relative fit among these models using Akaike's information criterion adjusted for small sample sizes ( $AIC_c$ ) and rescaled to  $AIC_c$  differences ( $\Delta_i$ ) and model probabilities ( $w_i$ ). We summed  $w_i$  among models sharing a common explanatory variable to assess the overall evidence that the variable was associated with the clutch initiation date ( $\sum w_i$ , Burnham and Anderson 2002).

*Nesting habitats.*— We examined all nests with data available on the plant species used for nesting (nesting substrates;  $n = 184$  nests in Alaska,  $n = 149$  nests in Canada) to test for spatial variation of these attributes across six regions: interior Alaska, coastal Alaska (south-central and southeast Alaska), western Canada (BC, NT, YT), central Canada (AL, SK, MB, ON), eastern Canada (QC, interior NL), and maritime Canada (NB, NS). We did not include nests from Canada that were found after the chicks had fledged ( $n = 28$  nests) because we were not certain that these were the nests from which the chicks had fledged. We first assigned each nest to one of the follow general substrate classes: conifers, deciduous tree, deciduous shrubs, and other; the latter including nests placed in grasses, sedges (*Carex* sp.), cattails (*Typha* sp.), or on the ground. We then used a log-linear model with a Poisson distribution to test whether the proportional use of substrates varied among the six regions across Alaska and Canada. We did so by first developing a main-factor effects model with region and nesting substrate, which allowed numbers of nests to vary by region and substrate. We then compared the fit of this model, using  $AIC_c$  to the full-factorial model, which allows proportions of nests in each substrate to vary by region. We tested whether nest heights varied regionally or among nesting substrates by examining the subset of 157 nests from Alaska and 133 nests from Canada that included information on both nest heights and nest substrates. Specifically, we used ANOVA and resultant  $AIC_c$  values to compare the relative fit among models of average nest height that included the intercept and the univariate, bivariate, and full-factorial effects of region and substrate.

We then examined the habitat data collected at 107 nests on military lands in Alaska (Anchorage and Tanana Flats) to (1) test for differences in the use of microhabitats between the two intensive study areas and (2) to identify habitat variables that distinguished nest sites from nearby random sites in each study area. First, we used ANOVA and compared between study areas the average distance of nests from surface water, distance to the nearest nest, height of nests above ground or water, and number of supporting stems, dbh, and height of substrates used as nest sites. We

compared the relative fit of models with and without the effects of study area using  $AIC_c$ . Next, we tested for selection of nesting substrates by comparing the frequencies that Rusty Blackbirds used each substrate for nest sites versus the proportional availability of the substrates within the 20 x 20-m nest areas. We pooled samples across nests and nest areas separately because of small sample sizes. We further pooled counts of substrates as follows because of low counts of nest use or availability: alders plus paper birch, black plus white spruce in Anchorage; alders plus willows, paper birch plus balsam poplar, black plus white spruce on the Tanana Flats. We then used log-linear models with a Poisson distribution and log-link function to test for departures of use from availability for each study area separately (Manly et al. 1993). We used the estimated parameters from the resulting log-linear models to calculate the ratios of proportional use to proportional availability following Manly et al. (1993, p. 141).

We then used univariate logistic regression with a matched-pair design (Hosmer and Lemeshow 2000) to test whether individual habitat variables could distinguish 20 x 20-m nest areas from nearby 20 x 20-m random areas not used for nesting. We ran separate analyses for Anchorage and Tanana Flats because we did not expect selection to be the same due to large differences in habitats (Matsuoka et al. *in review*). The habitat attributes that we included in the models were distance to water, distance to nearest nest, percent of the 20 x 20-m area with surface water, canopy cover, and tree and shrub stem densities by dbh class. For the latter, we combined counts of live and dead stems for each plant species because of high correlations ( $r > 0.4$ ) and because we found Rusty Blackbirds to nest commonly in both live and dead vegetation (see RESULTS). We compared the fit of the univariate logistic regressions within a study area using  $AIC_c$ .

*Fecundity and nest survival.* We examined the nests in Alaska ( $n = 104$  nests) and Canada ( $n = 28$  nests) with multiple observations of the final clutch and used ANOVA to test for mean differences in clutch sizes between Alaska and Canada. We did not include nests with a single observation of the clutch size because we sometimes found nests during egg laying. We then examined the Alaska data on clutches and developed nine ANOVA models of clutch sizes that included the intercept only, a univariate model with the covariate effects of clutch initiation date, and the univariate, bivariate, and full-factorial effects of year, location, and region. We did not include location and region in the same models. We compared the relative fit among these models using  $AIC_c$ .

We calculated maximum-likelihood estimates of daily nest survival and proportion of nests fledging at least one nestling (nesting success) following Dinsmore et al. (2002), in which survival is modeled as a function of covariates using a logit link. Sample size by study area included 39 nests from Anchorage, 14 nests from the Copper River Delta, 24 nests from Fairbanks, five nests from Innoko, 60 nests from Tanana Flats, and eight nests from Tetlin ( $n = 150$  nests total). This excluded 12 nests that were abandoned during construction, abandoned in early incubation after we banded the female, or had unknown fates (four nests each). We assessed nest survival across the six study areas in two stages. We first controlled for temporal variation by comparing the relative fit among 18 models of nest survival that included the intercept only and all combinations of either (1) the linear or quadratic effects of nest age (age and age<sup>2</sup>), (2) the linear or quadratic effects of date (date and date<sup>2</sup>), and (3) the categorical effects of year (Grant et al. 2005). Models with quadratic effects were second order polynomials that included both the linear and squared effects of age or date (Grant et al. 2005). When we found evidence for year effects, we assessed the resulting coefficients for each year and

combined years with coefficients that had overlapping 95% confidence intervals. We then tested for spatial variation in nest survival controlled for temporal variation by using the temporal model with lowest  $AIC_c$  and then adding the single effects of region (interior vs. south-central), study area, and the full factorial effects of region plus year and study area plus year.

We then examined the subset of 99 nests on military lands in Alaska (Anchorage and Tanana Flats) to determine if nest survival was related to specific habitat attributes used for nesting. This analysis excluded 8 nests with either unknown fates or that were abandoned following the banding of the adults. We used the methods above and first developed 18 models of temporal variation in nest survival. We then used the temporal model with lowest  $AIC_c$  and added to it individual nest habitat characteristics. Nest microsite variables included the categorical effects of minimum nest concealment ( $\leq 50\%$  concealed vs.  $> 50\%$  concealed), nest substrate (shrub, conifer, other), morbidity of the nesting substrate (live or dead), and the linear or quadratic effects of nest height and nest substrate height. Characteristics of the nest macrosite included distance to surface water, distance to nearest nest, and numbers of stems of willows or black spruce within the 20 x 20-m nest area. For the latter, we restricted stem densities to willows and black spruce because they were the dominant substrates used for nesting (black spruce in Anchorage, willow shrubs on the Tanana Flats).

For all models of nest survival we included each categorical covariate as a series of indicator variables; we rescaled each continuous habitat variable using a z-transformation (Dinsmore et al. 2002, Rotella et al. 2004). We compared the relative fit of models using  $AIC_c$  and used the delta method to calculate the standard error associated with our estimates of daily nest survival (Cooch and White 2009). Because we found substantial evidence for age<sup>2</sup> and date effects, we calculated nest success as the product of the daily estimates over the modal length of the nesting period from clutch initiation to the fledgling of young (29 days). We used the delta method to calculate the variance and 95% confidence intervals associated with our estimates of nest survival and nest success (Cooch and White 2009).

We used ArcGIS version 9.0 (ESRI Inc. 2005) to map the location of nests and study areas, Program MARK version 5.0 (White and Burnham 1999, Cooch and White 2009) to analyze data on nest survival, and SAS version 9.2 (SAS Institute 2008) to fit generalized linear models. We considered models with  $\Delta_i < 2.0$  to be best supported by the data (Burnham and Anderson 2002) and present all statistics  $\pm$  SE.

## RESULTS

### NESTING CHRONOLOGY AND CLUTCH SIZE

Rusty Blackbirds in Alaska and Canada constructed new nests for each nesting attempt and often placed their nests near old nests from previous years. We observed one pair of Solitary Sandpipers (*Tringa solitaria*) that hatched young from an old Rusty Blackbird nest in Anchorage in 2008. In Alaska, we observed 27 nests where the female constructed the nest while closely guarded by her apparent mate; copulations were observed during five of these observations but we never saw males assisting females in building. Most of our observations of nest building in Alaska were from 11–24 May ( $n = 25$  nests), but two late nests were observed under construction



on 4 and 9 June 2007 in Anchorage. The interval between the start of building and the laying of the first egg was three days for one nest and four days for four nests in Alaska.

Nests in Alaska and Canada were observed with eggs (Alaska: 9 May–26 June, Canada: 4 May–30 June) and nestlings (Alaska 25 May–8 July, Canada: 23 May–16 July) over similar ranges of dates. In Alaska, clutches were estimated to have been initiated from 6 May to 14 June, with most clutches (91% of 138 nests) initiated from 10–24 May (Fig. 2). A model of clutch initiation dates that included region in Alaska was best supported by the data (log likelihood  $[L] = -273.7$ ,  $n = 138$  nests, no. of parameters  $[K] = 3$ ,  $AIC_c = 553.6$ ,  $w_i = 0.44$ ). This model indicated that clutches were initiated an average of 4 days earlier in interior ( $\bar{x} = 12.7 \pm 0.6$  days,  $n = 96$  nests) compared to south-central Alaska ( $\bar{x} = 16.6 \pm 0.9$  days,  $n = 52$  nests; where day 1 = 6 May; Fig. 2) and had better fit than the model that included location ( $\Delta_i = 2.8$ ) and much better fit than the model with year or no effects ( $\Delta_i \geq 10.5$ ). The fit of univariate models with region or location were not improved when year or an interaction term were added; thus we did not find support that average dates of clutch initiation varied by year.

In Canada and Alaska, one egg was laid per day among 21 nests with multiple observations during egg laying ( $n = 25$  intervals between visits). In one nest in Canada, the first egg was laid before the female had finished lining the nest with fine grasses. In Alaska, females were often observed on eggs prior to clutch completion (seven of 21 nest visits during laying), but eggs during these observations were not typically warm to the touch like incubated eggs following clutch completion. We fitted three nests with temperature data loggers on the day the second egg was laid. In two nests, daytime temperatures were consistent with ambient temperatures until clutches were completed. In the third nest, daytime temperatures remained higher than ambient through egg laying. In all three nests, evening temperature were consistently higher than ambient prior to clutch completion. Both day and evening nest temperatures were consistently higher than ambient from clutch completion to fledging or failure.

The modal number of days from the laying of the last egg until the hatching of the first eggs in Alaska was 12 days ( $\bar{x} = 11.8 \pm 0.2$  days, range = 10–13 days,  $n = 18$  nests). Males did not incubate eggs but often delivered invertebrate prey to females who typically flew from the nest to a nearby tree or shrub where they gave begging calls, quivered their wings, and accepted the food. Chicks hatched from eggs over 1–2 days ( $n = 5$  nests) in Alaska. In all six study areas in Alaska, researchers noted that multiple pairs of blackbirds often mobbed them during their nest visits, particularly during the later stages of the nestling phase. The modal number of days from the onset of hatch to the fledging of young in Alaska was 12 days ( $\bar{x} = 11.5 \pm 0.2$  days, range = 10–13 days,  $n = 13$  nests). Males and females were observed feeding nestlings and newly fledged young both in Alaska and Canada.

## NESTS AND NEST SITES

The average dimensions of nests from Anchorage ( $n = 31$  nests), Tanana Flats ( $n = 63$ ), and Tetlin ( $n = 7$  nests) were: total outside diameter =  $14.1 \pm 0.2$  cm, total height =  $11.5 \pm 0.2$  cm, cup width =  $9.6 \pm 0.2$  cm, and cup depth =  $5.9 \pm 0.1$  cm. The outer frame and rim of these nests were constructed primarily of spruce, willow, or birch (*Betula* sp.) branchlets and coarse grasses which were often woven into the stems and branches of the tree or shrub used for nesting.

Lesser materials included mosses, the stems of horsetail (*Equisetum* sp.) and fireweed (*Epilobium augustifolium*), and plant down from cottongrass (*Eriophorum* sp.) and fireweed. The inner cup was comprised of mud, mosses, or organic shoreline detritus which were typically wet during construction and hardened when dried. The nest cup was often thinly lined with fine grasses or sedges; moose hair (*Alces alces*) commonly lined nests in Anchorage and Tanana Flats but was not observed in Tetlin.

Nests across Alaska ( $n = 184$ ) and Canada ( $n = 149$ ) were placed primarily in conifers ( $n = 199$ ) and deciduous shrubs ( $n = 114$ ); few nests were placed in deciduous trees and other substrates ( $n = 20$  nests; Fig. 3). A log-linear model that allowed the proportion of nests in each substrate to vary among regions ( $L = -34.2$ ,  $n = 333$  nests,  $K = 19$ ,  $AIC_c = 109.0$ ,  $w_i = 1.0$ ) had substantially better fit than the model where the proportion of nests in each substrate was constant among regions ( $K = 13$ ,  $\Delta_i = 186.4$ ). This model indicated that Rusty Blackbirds in all regions but interior Alaska were most likely to nest in conifers (Fig. 3).

Blackbirds placed nearly all of their nests (81–96%) in conifers in coastal Alaska and central, eastern and maritime Canada and a majority of their nests in conifers in western Canada (66%). A much smaller proportion of nests (15%) were placed in conifers in interior Alaska, where, unlike anywhere else, blackbirds placed most of their nests (78%) in shrubs (Fig. 3). In interior Alaska, 93 shrub nests were placed in willows, which were often dead ( $n = 26$  nests); one additional shrub nest was located in a dead alder. Small numbers of willow ( $n = 13$ ) and alder shrubs ( $n = 6$ ) were used as nest sites across the other regions (Fig. 3).

Of the nests placed in conifers, all in Alaska ( $n = 75$  nests) and the majority in Canada (80% of 124 nests) were located in spruces. Small numbers of other conifers were used as nest substrates in Canada including balsam firs ( $n = 14$  nests in Ontario, Quebec, Newfoundland, and New Brunswick), northern white cedar (*Thuja occidentalis*;  $n = 4$  nests in Ontario, Quebec, and New Brunswick), and unidentified conifers ( $n = 6$  nests). Most spruce nests were in black spruce ( $n = 76$  nests), which were used as nest sites across all regions, except for the coastal rainforest zone in Alaska where 15 nests on the Copper River Delta and one nest near the Stikine River were placed in live Sitka spruce. Small numbers of white spruce were also used as nest sites over a broad region including interior Alaska ( $n = 11$  nests), south-central Alaska ( $n = 7$  nests in Anchorage), the Yukon Territory ( $n = 2$  nests), and Ontario ( $n = 5$  nests). Most nests in unidentified spruces (62% of 58 nests) were located in the introgression zone between black and red spruce (*P. rubens*) in Quebec, New Brunswick, and Nova Scotia (Gordon 1976). In interior Alaska and Anchorage, 39% of the 59 spruces used for nest sites were dead.

Eleven nests were also found in deciduous trees including paper birch ( $n = 4$  nests in Anchorage, Quebec, and Tanana Flats), balsam poplar ( $n = 3$  nests in British Columbia and Tanana Flats), one nest in a red maple (*Acer rubrum*) in Nova Scotia, and one nest in a pin cherry (*Prunus pensylvanica*) in Ontario. Two nests were located in grasses (Tanana Flats) and six nests were in emergent sedges (*Carex* sp.) and cattails (*Typhus* sp.) in Anchorage, Nova Scotia, and the Tanana Flats. A single nest in British Columbia was found on the ground on a beaver (*Castor canadensis*) dam.

The average heights of nests across Alaska and Canada was  $1.6 \pm 0.1$  m ( $n = 321$  nests) but varied by substrate used for nesting ( $L = -164.6$ ,  $n = 290$  nests,  $K = 5$ ,  $AIC_c = 339.2$ ,  $w_i = 1.0$ ). Nest heights from lowest to highest were grass/sedges/cattails/ground =  $0.23 \pm 0.06$  m (range = 0–0.5 m;  $n = 9$  nests), shrubs =  $1.0 \pm 0.1$  m (0–4.1 m;  $n = 93$  nests), deciduous trees =  $1.3 \pm 0.4$  m (range = 0.3–5.0 m;  $n = 10$  nests), and conifers =  $2.0 \pm 0.2$  m (range = 0–16.2 m,  $n = 178$  nests). The model of nest height with an intercept only was not well supported by the data ( $\Delta_i = 21.0$ ).

*Military lands in Alaska.* We found 21 and 23 nests in Anchorage in 2007 and 2008, respectively; and 32 and 31 nests in 2007 and 2008, respectively on the Tanana Flats. Similar to regional patterns (Fig. 3), Rusty Blackbirds placed 93% of 44 nests in spruces in Anchorage ( $n = 32$  nests in black spruce and 7 nests in white spruce) and 76% of 63 nests in shrubs on the Tanana Flats ( $n = 47$  nests in willows and 1 nest in alder). All models of nest microsite characteristics that included study area had far better fit ( $w_i = 1.0$ ) than their equivalent models with only an intercept ( $\Delta_i \geq 11.4$ ). Substrates used for nesting in Anchorage were on average nearly 2-times taller and 3-times greater in dbh and had 3-fold fewer stems supporting nests than on the Tanana Flats. Nests in Anchorage were also nearly 2-times higher, 3.5-times farther apart, and 3-times farther away from surface water than nests on the Tanana Flats (Table 1). There was limited evidence of colony nesting as only four pairs of nests were within 50 m of each other (two each in Anchorage and Tanana Flats). Nests on the Tanana Flats were less concealed by vegetation (6% of 62 nests more than 50% concealed) than in Anchorage (46% of 44 nests were more than 50% concealed).

When we compared the proportion of nests in shrubs, deciduous trees, and conifers to the proportional availability of these substrates, we found evidence that blackbirds selectively nested within nest areas in both Anchorage ( $L = -13.1$ ,  $n = 42$  nests and 4154 stems,  $K = 5$ ,  $AIC_c = 36.3$ ,  $w_i = 1.0$ ) and the Tanana Flats ( $L = -19.0$ ,  $n = 58$  nests and 4840 stems,  $K = 7$ ,  $AIC_c = 52.0$ ,  $w_i = 1.0$ ). Ratios of proportional use to availability ( $\beta > 1$  indicated selection,  $\beta < 1$  indicated avoidance) indicated that Rusty Blackbirds in Anchorage nested in black and white spruce in proportion to their availability ( $\beta = 1.3 \pm 0.5$ ) and avoided nesting in alders and paper birch ( $\beta = 0.1$ ), the reference category. Rusty Blackbirds on the Tanana Flats selectively nested in black and white spruce ( $\beta = 5.0 \pm 1.2$ ), used willows and alders in proportion to availability ( $\beta = 1.5 \pm 0.4$ ), and avoided nesting in paper birch and balsam poplar ( $\beta = 0.3$ ), the reference category.

Areas used for nesting by Rusty Blackbirds were characterized by a predominance of black spruce and a scarcity of willows in Anchorage with the opposite true on the Tanana Flats. Nest areas in both areas had a sparse tree canopy (Table 2). We compared habitat characteristics between nest areas and paired random areas not used for nesting and found evidence for nest-site selection in Anchorage but not for the Tanana Flats where the logistic regression with an intercept only ( $L = -43.7$ ,  $n = 63$  matched pairs of nests and random areas,  $K = 2$ ,  $AIC_c = 87.3$ ,  $\Delta_i = 1.0$ ) was not improved by 2  $AIC_c$  values by adding any of the habitat covariates ( $K = 3$ ,  $\Delta_i = 0.0$ – $3.1$ ; Table 2). In Anchorage, the model of nest-site selection that included the total number of small black spruce ( $2.5 \text{ cm} \leq \text{dbh} < 8 \text{ cm}$ ) was best supported by the data ( $L = -26.9$ ,  $n = 44$  matched pairs of nests and random areas,  $K = 3$ ,  $AIC_c = 58.1$ ,  $w_i = 0.60$ ). This model indicated that Rusty Blackbirds nested in areas with relatively high densities of small black spruce

compared to matched random sites ( $\beta = 0.019 \pm 0.008$ ); other models of nest site selection were not well supported by the data ( $\Delta_i = 3.6\text{--}7.1$ ; Table 2).

## FECUNDITY AND NEST SUCCESS

Among nests with multiple observation of the final clutch size in Alaska and Canada, 48 nests had 6 egg clutches, 62 nests had 5 eggs, 21 nests had 4 eggs, and one nest in Canada had a 3 egg clutch. One additional nest on the Tanana Flats was found with 7 nestlings. An analysis of variance model that compared mean clutch size between Alaska and Canada ( $L = 54.7$ ,  $n = 132$  nests,  $K = 3$ ,  $AIC_c = -103.2$ ) had substantially better fit than the model with only an intercept ( $\Delta_i = 20.2$ ). This model indicated that clutches in Alaska ( $\bar{x} = 5.3 \pm 0.1$  eggs, mode = 5 eggs,  $n = 104$  nests) were larger than those in Canada ( $\bar{x} = 4.6 \pm 0.1$  eggs, mode = 4 eggs,  $n = 28$  nests). For the subset of nests from Alaska, clutch size was best described by a model that included clutch initiation date ( $L = 55.2$ ,  $n = 104$  nests,  $K = 3$ ,  $AIC_c = -104.4$ ). This model indicated that clutch size declined as the nesting season progressed ( $\beta_0 = 5.87 \pm 0.15$ ,  $\beta_{\text{initiation date}} = -0.04 \pm 0.01$ ). Other models with the effects of region, study area, year, or an intercept only were not well supported by the data ( $\Delta_i \geq 9.9$ ).

Within Alaska, egg viability was high and partial nestling reductions were quite low. Among the 69 nests that we observed surviving through incubation period,  $90 \pm 2\%$  of 373 eggs hatched. Among the subset of 63 of these nests that fledged young,  $96 \pm 2\%$  of 312 hatchlings fledged. For the 150 nests monitored for survival in Alaska; 96 fledged young, 54 failed, and four nests had unknown fates. Among failed nests; 48 were lost to predators (89%), four failed from unknown causes, and one nest in sedges and one nest in cattails sunk into water. We observed one predation events during incubation by a red squirrel (*Tamiasciurus hudsonicus*). Although we rarely witness nest predation, we often observed adult Rusty Blackbirds mobbing Gray Jays (*Perisoreus canadensis*) or Black-billed Magpies (*Pica pica*) in our study areas. Less commonly, we observed blackbirds chasing Common Ravens and a variety of raptors including Bald Eagle (*Haliaeetus leucocephalus*), Northern Harrier (*Circus cyaneus*), Sharp-shinned Hawk (*Accipiter striatus*), Northern Goshawk (*A. gentilis*), Red-tailed Hawk (*Buteo jamaicensis*), and Merlin (*Falco columbarius*). We even observed adult blackbirds on single instances chasing Solitary Sandpipers, Wilson's Snipe (*Gallinago delicata*), and American Robins (*Turdus migratorius*). We never observed pairs to renest after successfully fledging young, but we observed two color-marked females renesting 57 m and 196 m from their failed first nests.

All models of daily nest survival in Alaska that included the effects of year indicated that nest survival was similar in 2007 and 2008. For parsimony, we therefore reduced models with year effects to 2006 versus 2007 and 2008 combined. With years reduced in this manner, daily nest survival averaged  $0.947 \pm 0.012$  in 2006 [nest success ( $S$ ) = 0.21 [95% CI = 0.08–0.37]],  $0.985 \pm 0.002$  in 2007 and 2008 [ $S = 0.64$  (95% CI = 0.54–0.72)], and  $0.980 \pm 0.003$  all three years combined [ $S = 0.56$  (95% CI = 0.47–0.64)]. Daily nest survival, however, was best described by a temporal model that included age<sup>2</sup>, date, and year ( $L = -192.5$ ,  $K = 5$ ,  $AIC_c = 395.0$ ,  $w_i = 0.42$ ) and indicated that daily nest survival declined with date, first declined and then increased with nest age, and was low in 2006 compared to 2007 and 2008 combined (logit scale;  $\beta_0 = 6.89 \pm 1.32$ ,  $\beta_{\text{age}} = -0.32 \pm 0.15$ ,  $\beta_{\text{age}^2} = 0.016 \pm 0.009$ ,  $\beta_{2007-2008} = 1.16 \pm 0.30$ ; Fig. 4). Standardized to the median nest initiation date of May 16 (date = 7 in the model), we calculated the product of

the daily estimates of nest survival over the modal nesting period (29 days) and found that nest success was 0.34 in 2006 (95% CI = 0.17–0.67) and 0.71 in 2007 and 2008 combined (95% CI = 0.59–0.85). This model had better fit than the second best model which included the effects of age<sup>2</sup>, date<sup>2</sup>, and year ( $K = 6$ ,  $\Delta_i = 2.0$ ,  $w_i = 0.16$ ) and the third best model with age<sup>2</sup> and year ( $K = 4$ ,  $\Delta_i = 2.3$ ,  $w_i = 0.14$ ). Summing model weights we found the most support for models with year effects ( $\sum w_i = 1.0$ ), age<sup>2</sup> ( $\sum w_i = 0.72$ ), and date ( $\sum w_i = 0.62$ ); we found less support for models with the linear effects of age ( $\sum w_i = 0.13$ ) and the quadratic effects of date ( $\sum w_i = 0.22$ ) and no support for the model with the intercept only ( $\Delta_i = 27.6$ ,  $w_i < 0.001$ ). The best temporal model was not improved by adding the additional effects of study area, study area\*year, region, or region\*year ( $\Delta_i = 0.2$ – $2.7$ ).

On military lands in Alaska, we found the most support for a temporal model that included age<sup>2</sup> ( $L = -117.1$ ,  $K = 3$ ,  $AIC_c = 240.2$ ,  $w_i = 0.32$ ). Similar to the model in Fig. 4, daily nest survival first declined from ages 0–21 and then rose thereafter. The next four best fitting models, in decreasing order of relative fit, included age<sup>2</sup> in combination with either date, year, date<sup>2</sup>, or date plus year ( $\Delta_i = 0.9$ – $2.9$ ). Summing model weights we found the most support for models with age<sup>2</sup> ( $\sum w_i = 0.83$ ); far less support for models with age, date, date<sup>2</sup>, or year ( $\sum w_i = 0.14$ – $0.34$ ); and no support for the model with the intercept only ( $\Delta_i = 17.7$ ,  $w_i < 0.001$ ). The model with age<sup>2</sup> ( $\Delta_i = 3.8$ ) was improved by more than two  $AIC_c$  values by adding either the substrate used for nesting ( $K = 5$ ,  $\Delta_i = 0.0$ ), the quadratic effect of the height of the plant used for nesting ( $K = 5$ ,  $\Delta_i = 0.8$ ), the density of black spruce stems in the area used for nesting ( $K = 4$ ,  $\Delta_i = 1.1$ ), or the quadratic effect of nest height ( $K = 5$ ,  $\Delta_i = 1.5$ ). None of these models were improved by more than one  $AIC_c$  value by adding the effects of study area. The model with age<sup>2</sup> was not improved by adding either the linear effects of nest height, the linear effects of the height of vegetation used for nesting, or the effects of study area, nest cover, morbidity of the vegetation used for nesting, densities of willow stems, distance to water, or distance to nearest nests ( $\Delta_i = 2.2$ – $5.7$ ).

The model with age<sup>2</sup> and nesting substrates was further improved by 1.5  $AIC_c$  values by reducing nesting substrates to conifers versus all others substrates combined (logit scale;  $\beta_0 = 9.8 \pm 2.9$ ,  $\beta_{age} = -0.63 \pm 0.31$ ,  $\beta_{age^2} = 0.015 \pm 0.008$ ,  $\beta_{conifer} = 1.00 \pm 0.38$ ). When we calculated the product of the survival rates for each nest age using this model, we found that nest success in conifers was 0.78 (95% CI = 0.64–0.96) and in other substrates combined was 0.52 (95% CI = 0.33–0.80). The fit of the model with age<sup>2</sup> and nesting substrates was not improved by reducing substrates to shrubs versus all other substrates combined.

The model with age<sup>2</sup> and the quadratic effect of the height of the plants used for nesting (logit scale;  $\beta_0 = 11.1 \pm 3.0$ ,  $\beta_{age} = -0.69 \pm 0.31$ ,  $\beta_{age^2} = 0.016 \pm 0.008$ ,  $\beta_{substrate\ height} = 0.53 \pm 0.23$ ,  $\beta_{substrate\ height^2} = -0.19 \pm 0.07$ ) indicated that daily nest survival first increased as nests were placed in vegetation up to 6 m in height and then began to decline with increases in vegetation height above 11 m (Fig. 5). This model had estimated coefficients that were nearly identical to the model with age<sup>2</sup> and the quadratic effect of nest height due to the high correlation ( $r = 0.57$ ) between nest height and the height of vegetation used for nesting. Finally, the model of nest survival that included age<sup>2</sup> and the density of black spruce indicated that nest survival increased with increases in the density of black spruce in the area used for nesting ( $\beta_{black\_spruce} = 0.42 \pm 0.23$ ).

## DISCUSSION

In our analysis of Rusty Blackbird nests from across Alaska and Canada, we found that (1) the species has a widespread affinity for conifers, particularly spruces, for nest sites; (2) that selectivity for spruces on military lands in Alaska was adaptive in terms of relatively high reproductive success; and (3) that nest survival across Alaska varied within and among years but was generally high and not at chronically low levels that would strongly contribute to the species' long-term and range-wide decline. Across the coastal region of Alaska and the boreal region of Canada, 85% of 212 nests were placed in conifers with most conifer nests in spruces (100% in Alaska, 80% in Canada). This was quite similar to New England where 93% of 65 nests were in conifers and 64% of conifer nests were placed in spruces (Kennard 1920, Ellison 1990, Powell et al. *in press*). The use of black spruce as nest sites was particularly widespread and occurred in all regions of Alaska and Canada except in the coastal rainforest zone in Alaska, the only area where Rusty Blackbirds nested in young Sitka spruce, the principal conifer available. Similar to our findings, Erskine (1977) described the Rusty Blackbird as characteristic of black spruce bogs based on Breeding Bird Censuses conducted across boreal Canada. Rusty Blackbirds were also found breeding at 75% of 63 lakes in districts with black spruce in Quebec (DesGranges and Houde 1989) and 74% of Rusty Blackbirds encountered during surveys in the Northwest Territories were in black spruce muskegs often near standing water and lakes (Machtans et al. 2007). Thus, black spruce near emergent vegetation, ponds, and particularly lakes (Matsuoka et al. *in review*) may be favored combinations of habitat features for breeding across much of the species' range.

Our nest monitoring on military sites in Anchorage, Alaska indicated that the use of spruce by Rusty Blackbirds was selective and resulted in relatively high rates of nesting success. Rusty Blackbirds in Anchorage selected areas for nesting that had relatively high densities of small black spruce and placed their nests primarily in such trees. Birds nesting in dense spruce benefitted reproductively as nest survival increased with black spruce density. We suspect that areas with high densities of black spruce may have lowered predation rates by increasing the number of potential nest sites that predators had to search, which is in accordance with the potential-prey-site hypothesis (Martin 1993). Nesting in spruce trees, particularly small spruce, had additional advantages as nest success in both Anchorage and the Tanana Flats was slightly higher for Rusty Blackbird nests placed in spruces (78% of nests fledged young) than in deciduous vegetation (52% of nests fledge young) and nest survival decreased when nests were placed in trees exceeding 11 m in height. Deciduous vegetation tended to leaf out after Rusty Blackbirds began to incubate their eggs in Alaska and may therefore have provided less direct cover from predators than conifers. However, we did not find nest survival to be associated with level of nest concealment. Relative to tree heights, all nesting trees above 9 m in height were spruces. Taller spruce are more likely to produce cones (Greene et al. 2002) and attract foraging red squirrels, a major nest predator in the boreal forest (Rangen et al. 1999, Bayne and Hobson 2002, Willson et al. 2003) and the one species we observed preying on Rusty Blackbird eggs. Thus, the use of small spruces for nesting may be an adaptation to reduce nest predation by red squirrels, which range across North America's boreal forest (Steele 1998). Nesting in wetlands may also be advantageous due to low densities of red squirrels and corvids (DeSanto and Willson 2001) and lower nest predation rates relative to uplands (Robertson 1972, DeSanto and Willson 2001).

Similar to our study, Rusty Blackbirds in New England nested in small spruce and firs at sites with dense growth of these conifer species (Kennard 1920; Ellison 1990; Powell et al. *in review*). While the use of these habitat characteristics resulted in high rates of nest survival in undisturbed wetlands in Alaska, they did not in human-altered landscapes in New England where Rusty Blackbirds often nested in dense young conifers regenerating from recent timber harvests adjacent to wetlands (Ellison 1990, Powell et al. *in review*). Within harvested sites, Rusty Blackbirds in New England had much lower rates of nest success (7–36% fledged young) than pairs nesting in undisturbed wetlands with older, but stunted conifers (100% of nests fledged young). Habitat characteristics of harvested sites and undisturbed wetlands were quite similar with the exception of landscape position (upland and wetland, respectively) and the average age of the small conifers used for nesting (14 and 28 years, respectively). Thus, recent harvests appear to attract nesting Rusty Blackbirds into upland habitats that they would otherwise avoid; once in the upland habitats they suffer high rates of nest predation (Powell et al. *in review*).

Although Rusty Blackbirds seem to be sensitive to timber harvest in New England, the species appears to be adaptable to natural disturbances that occur frequently and at large scales in the boreal forest (Blais 1983, Johnson 1992, Matsuoka et al. 2006). We often observed Rusty Blackbirds nesting in willows and spruces in Alaska that were recently killed from flooding or outbreaks of bark beetles (*Dendroctonus rufipennis* or *Ips* sp.). In New England the species has also been observed nesting in dead spruces in New England (Kennard 1920) and areas flooded by beavers (Ellison 1990). Unlike Red-winged Blackbirds (*Agelaius phoeniceus*), we found no evidence of decreased nest survival in dead versus live vegetation (Dinsmore and Dinsmore 2007). Relative to fire, Machtans et al. (2007) found no changes in Rusty Blackbird abundance or occupancy between 1975 and 2006 despite fires occurring during the intervening years in the forests surrounding 13 of 45 sampled lakes. The black spruce forests favored for nesting by Rusty Blackbirds are quite flammable in general, with a mean fire return interval of 79 years on the Kenai Peninsula, Alaska (DeVolder 1999), and fires may be advantageous to Rusty Blackbirds by reducing densities of nest predators (Robertson and Hutto 2007) such as red squirrels (Koprowki et al. 2006).

The only region in our study where we did not see a dominant use of spruce as nests sites was interior Alaska where Rusty Blackbirds instead placed 78% of 121 nests in shrubs, nearly all of which were in willows. Within this region on the Tanana Flats, a mixture of willow species numerically dominated the vegetation in the areas used for nesting and within these areas blackbirds placed their nests in willows in proportion to their availability. We observed this same pattern with spruce in south-central Alaska in Anchorage. Nests on the Tanana Flats and Anchorage were on average quite close to surface water (8 m and 30 m, respectively) so birds in both areas may have simply been using the dense vegetation that was near water. However, spruces were quite rare on the Tanana Flats but used in much greater proportion than expected by their availability. Furthermore, alders were also common in nest areas in Anchorage, the Tanana Flats, and Maine (Powell et al. *in review*) but almost never used as nest sites (2% of 333 nests in Alaska and Canada; 0% of 63 nests in New England; Kennard 1920, Ellison 1990, Powell et al. *in review*). Alders may be avoided either due to intrinsic preferences for conifers (Parrish 1995) or willows, or due to a lack of proper structure to support Rusty Blackbird nests which were quite large and typically woven into multiple stems and branches. For similar reasons, grasses, sedges, and cattails were likely avoided as nests sites. One nest in sedges and one nest in cattails

failed as they sank into water and low nesting in general may be avoided due to the higher risk of flooding. This might explain why the average nest heights of Rusty Blackbird breeding in Alaska, Canada (1.6 m), and New England (1.7 m; Powell et al. *in review*) were all relatively high compared to the nests of other North American blackbirds (Orians 1985).

We found that daily nest survival rates for Rusty Blackbirds were temporally variable in Alaska with survival highest during laying, declining thereafter through hatch, and increasing slightly during the last 8 days of the nestling period (Fig. 4). This was similar to the pattern of daily nest survival among Red-winged Blackbirds in Connecticut (Robertson 1972) and Missouri (Cao et al. 2008) and grassland sparrows in North Dakota (Grant et al. 2005) whereby nest survival was low during hatching and increased when adults became increasingly defensive as fledging approached (Robertson 1972, Grant et al. 2005). Nest survival of Rusty Blackbirds also declined linearly across the breeding season which was concurrent with the seasonal decline in clutch size. This decline in fecundity might explain why the species has not been found to renest after successfully fledging young in Alaska (this study) or New England (Kennard 1920, Powell et al. *in review*). Second broods may further be precluded because juveniles must undergo a nearly complete first-basic molt prior to autumn migration that is much more costly, in terms of time and energy, than the typical first-basic molt among passerines that does not include the flight feathers (Pyle et al. 1997).

Although nest success was relatively low in Alaska in 2006 (21%) and low in regenerating clearcuts in New England from 2005–2008 (Powell et al. *in review*), the overall pattern developing from nesting studies in Alaska and New England does not support a hypothesis that declining Rusty Blackbirds are suffering from chronically low rates of nest success. Nest success of Rusty Blackbirds in Alaska did vary by year but was high in both 2007 and 2008 (64%) and averaged 56% across the three years combined. The average rate was quite similar to that of Rusty Blackbirds nesting in New England (62%, Powell 2008), and much higher than the average nest success rate for Red-winged, Yellow-headed, and Brewer's blackbirds (30–39%; Martin 1995). We cannot explain why nest survival was so low in 2006 in Alaska; however, most nest losses in our study were due to predation (89% of losses) and annual nest predation rates have also been found to be quite variable for Red-winged Blackbirds (Beletsky and Orians 1996, Dinsmore and Dinsmore 2007). Clutches in Alaska averaged 5.3 eggs, which was slightly larger than clutches in Canada (4.6 eggs) or New England (4.5 eggs; Powell et al. *in review*) and much larger than those of temperate breeding Red-winged Blackbirds whose average clutch sizes ranged from 2.4–3.7 eggs among 20 studies (Yasukawa and Searcy 1995). This pattern follows the latitudinal increase in clutch size that is common among passerine birds (Kulesza 1989) and is thought to be a function of either greater food availability in northern latitudes (Ricklefs 1980) or lower nest predation risk (Martin 1995). Incidence of nestling starvation was particularly low in Alaska; nests that fledged young successfully reared 96% of their hatchlings.

Similar to nest survival, the viability of Rusty Blackbird eggs in Alaska was also quite high with 90% of the eggs that avoided predation and flooding hatched. This was similar to New England where only two addled eggs were found among 43 Rusty Blackbird nests (Powell et al. *in review*). We had expected the incidence of addled eggs to be higher in New England because the levels of methylmercury in the blood of adult Rusty Blackbirds was three-times higher in New England, Nova Scotia, and New Brunswick than levels measured in birds sampled on our study



areas in Alaska. Levels in New England and the Maritime Provinces were equivalent to the levels causing embryo mortalities in other species of birds (Edmonds et al. *in review*). Rusty Blackbirds across this region are declining at particularly high rates (Sauer et al. 2008; Powell 2008; Maritime Breeding Bird Atlas, unpublished data), so the high levels of methylmercury that are accumulating from the atmospheric fallout of industrial pollution (Driscoll et al. 2007) may be reducing fitness by lowering physiological condition and survival of Rusty Blackbirds rather than causing reproductive dysfunction. Likewise, if events during the non-breeding season, such as losses or degradation of bottomland forests, are contributing disproportionately to the species' decline (Greenberg and Droege 1999), then such effects will likely be reflected in lowered body condition or lower survival rates (Greenberg et al. 2010). Thus, studies that examine adult and juvenile survival are needed, particularly since nest success is not clearly limited. Such studies would be particularly useful if they were incorporated into carefully designed cross-seasonal investigations aimed at partitioning the effects of breeding versus wintering events on the physiological condition, survival, and population growth rate of Rusty Blackbirds (Sillert and Holmes 2002, Greenberg et al. 2010). Such investigations for migratory species are rare but sorely needed both to understand the mechanisms and address the causes of migratory bird declines (Greenberg and Marra 2005).

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Figure 1. Distribution of Rusty Blackbird nests found in Alaska ( $n = 184$  nests) and Canada ( $n = 230$  nests). Records of nests in Canada were from 1887–2008 and were submitted to Project NestWatch (Bird Studies Canada, unpublished data). Most nests in Alaska were from studies of Rusty Blackbirds from 2006–2008 in 1) Innoko National Wildlife Refuge (NWR), 2) Fairbanks and adjacent Tanana Flats Training Area, 3) Tetlin NWR, 4) Elmendorf Air Force Base and adjacent Fort Richardson near Anchorage, and 5) Copper River Delta.

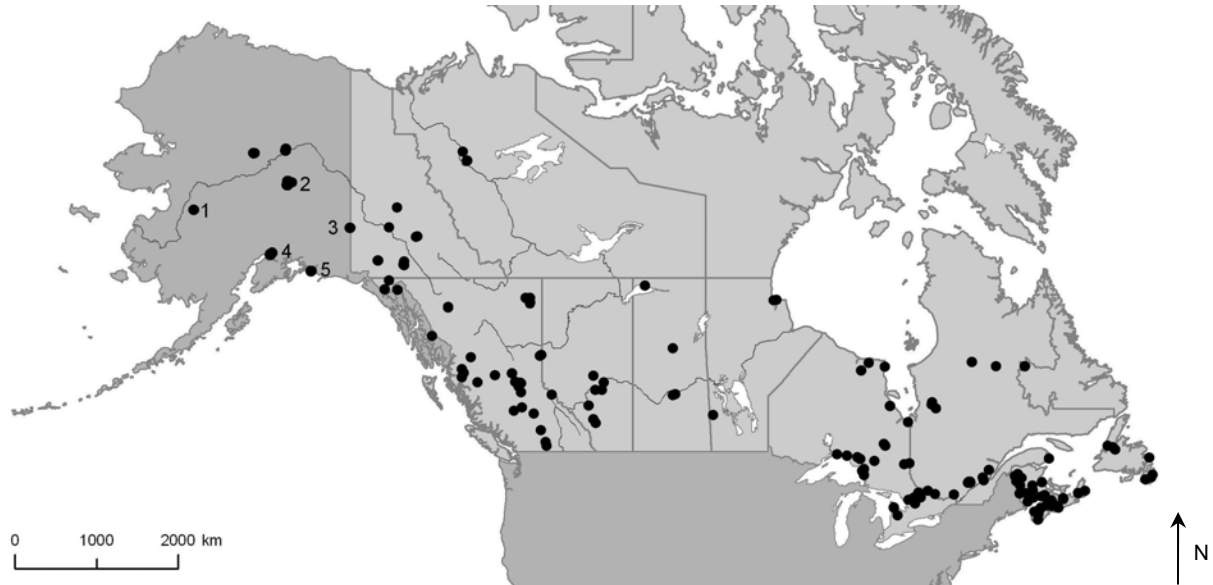


Figure 2. Dates of clutch initiations among Rusty Blackbirds nesting in interior (□, n = 86 nests) and south-central Alaska (■, n = 52 nests), 2006–2008.

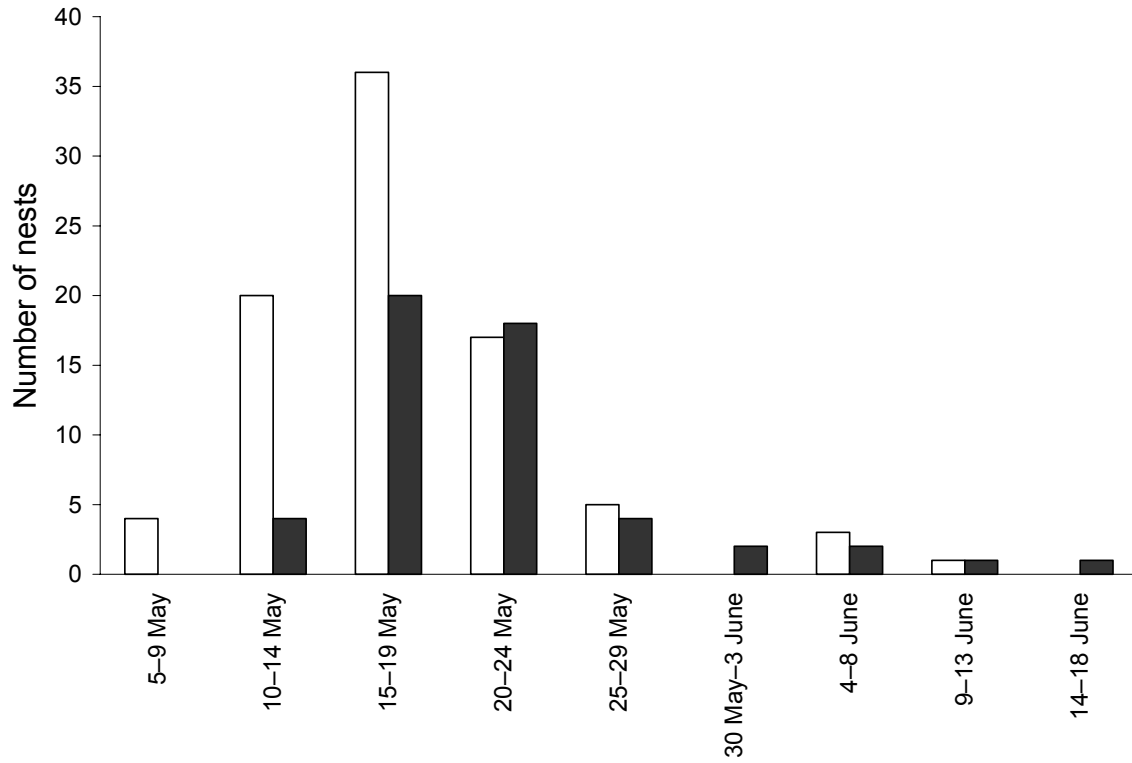


Figure 3. The proportion of Rusty Blackbird nests in each region of Alaska and Canada (CAN) that were placed on the ground or in grasses, sedges, or cattails ( $\square$ ,  $n = 9$  nests); deciduous shrubs ( $\blacksquare$ ,  $n = 114$ ); deciduous trees ( $\boxtimes$ ,  $n = 11$ ); and conifers ( $\blacksquare$ ,  $n = 199$ ). Regional data are presented from northwest to southeast across the species' breeding range.

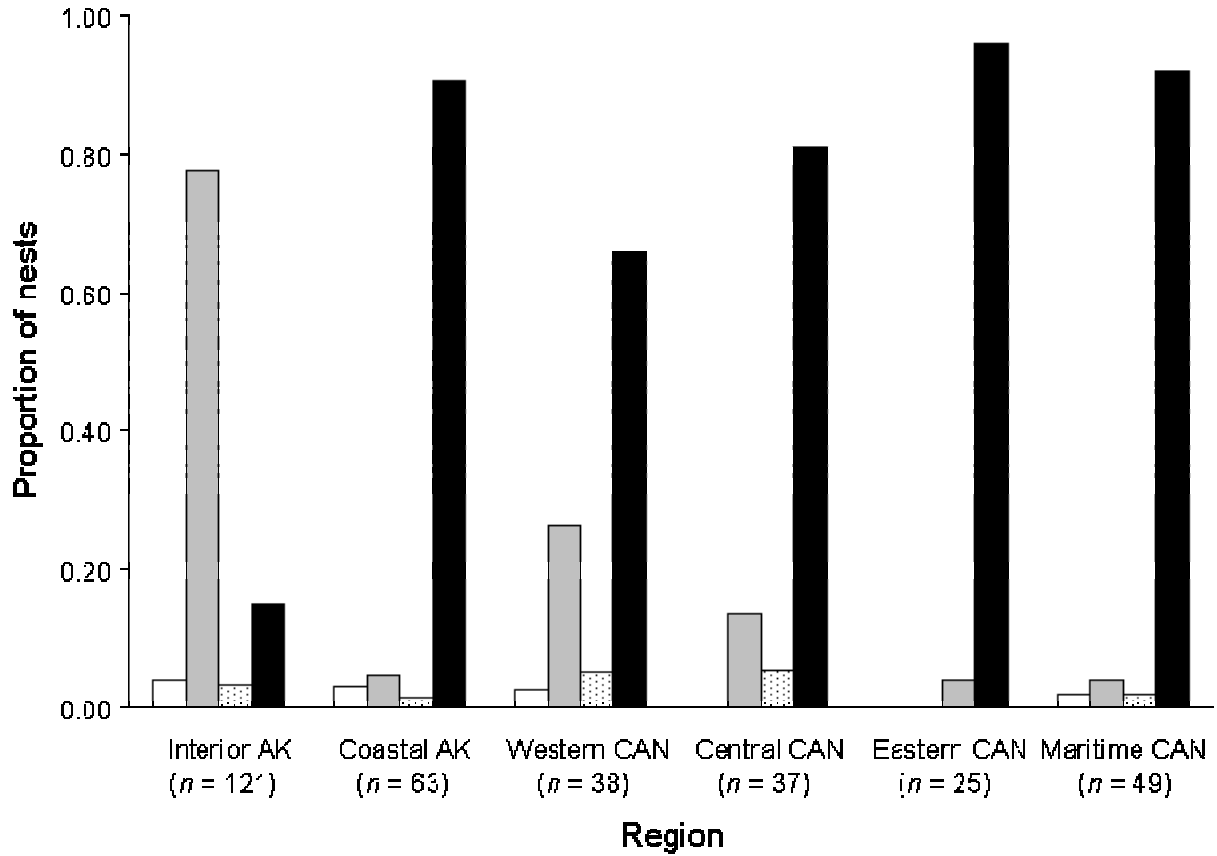


Figure 4. Daily nest survival rate of Rusty Blackbirds ( $n = 150$  nests) in Alaska in relation to nest age (days) and year (red = 2006, blue = 2007 and 2008 combined). Estimates of daily nest survival on day 0, the egg initiation date, are standardized to May 17. The dashed lines denote the 95% CI.

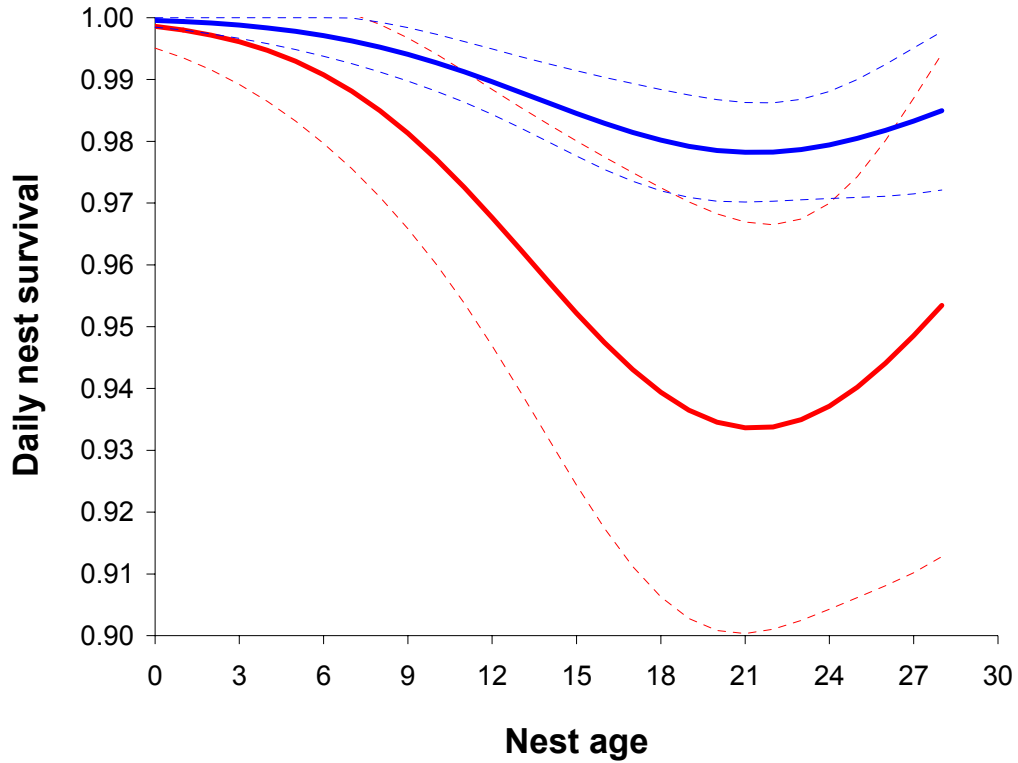




Figure 5. Daily nest survival rate of Rusty Blackbirds in relation to the height of vegetation used for nesting on military lands in Alaska, 2007–2008. Survival rates are based on a nest age standardized to day 10.

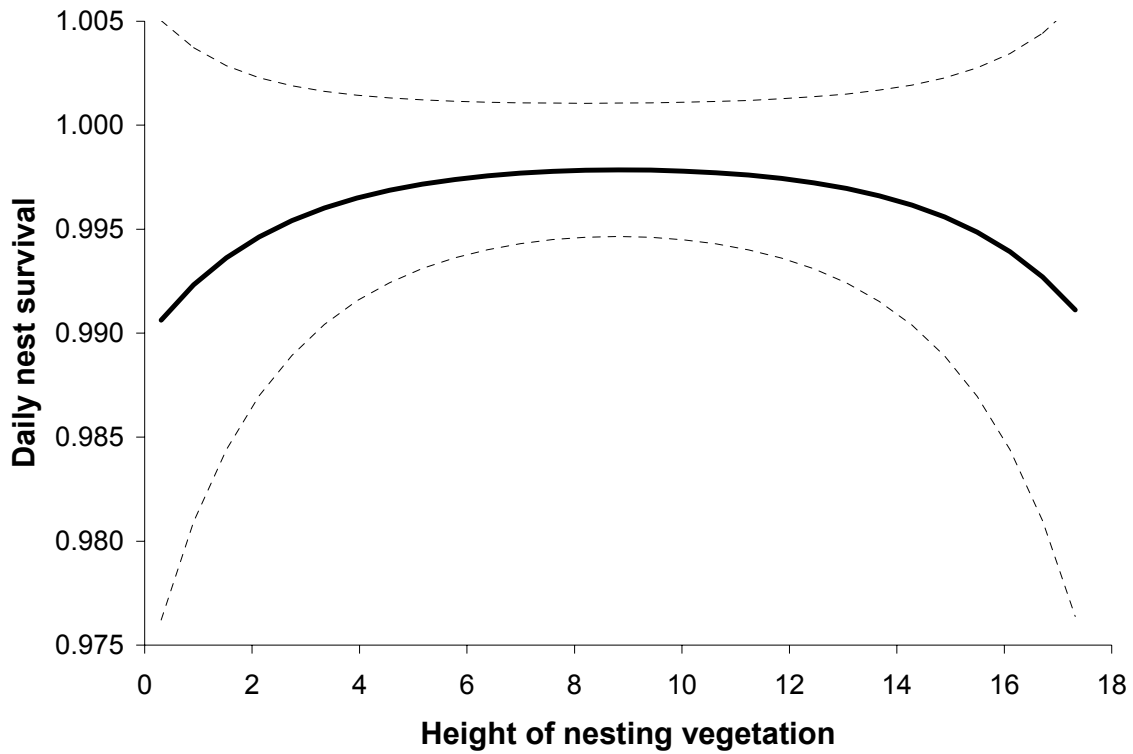


Table 1. Comparisons of micro-site characteristics [mean  $\pm$  SE (range) or proportion] of Rusty Blackbird nests in Anchorage and Tanana Flats, Alaska, 2007–2008. Most nests in Anchorage were placed in black spruce ( $n = 32$ ); most nests on the Tanana Flats were placed in willows ( $n = 47$  nests).

Variable <sup>1</sup>	Anchorage	<i>n</i>	Tanana Flats	<i>n</i>
Number of supporting stems	1.5 $\pm$ 0.1 (1–4)	42	4.3 $\pm$ 0.3 (1–11)	58
Height of supporting stems (m)	6.6 $\pm$ 0.7 (0.9–19.8)	42	3.6 $\pm$ 0.3 (0.4–9.5)	57
Nest height (m)	3.2 $\pm$ 0.5 (0.1–16.2)	43	1.3 $\pm$ 0.2 (0.2–12.0)	61
Diameter-at-breast-height (cm)	9.8 $\pm$ 0.8 (1–24)	42	3.2 $\pm$ 0.3 (0.7–13.2)	50
Distance to surface water (m)	30.6 $\pm$ 6.3 (0–185)	44	8.2 $\pm$ 2.7 (0–150)	63
Distance to nearest nest (m)	866 $\pm$ 213 (24–5437)	44	246 $\pm$ 19 (26–699)	62
Proportion nests >50% concealed <sup>2</sup>	0.46	44	0.06	62

<sup>1</sup>We did not measure dbh or count supporting stems for nests that were placed in grasses, sedges, or cattails ( $n = 2$  nests in Anchorage and 5 nests on the Tanana Flats); we did not measure dbh for nest in trees or shrub shorter than breast height (1.4 m;  $n = 8$  nests on the Tanana Flats). Sample size varied in other variables because of missing values.

<sup>2</sup>Percent nest concealment was visually estimated in quarterly increments at each nest from 1-m above, below, and from each cardinal direction. We present the proportion of nests that were at least 50% concealed from all directions.

Table 2. Habitat characteristics of areas used for nesting by Rusty Blackbirds in comparison<sup>1</sup> to matched random areas not used for nesting in Anchorage and Tanana Flats, Alaska 2007–2008.

Variable <sup>2</sup>	Diameter class	Anchorage ( <i>n</i> = 44 matched pairs)			Tanana Flats ( <i>n</i> = 63 matched pairs)		
		Nests	Random	$\Delta_i$	Nests	Random	$\Delta_i$
Alder	2.5 cm ≤ dbh < 8 cm	15.6 ± 4.2	8.6 ± 2.7	4.9	26.1 ± 5.9	25.3 ± 7.6	3.1
	dbh ≥ 8 cm	0.9 ± 0.6	0.3 ± 0.2	6.5	0.7 ± 0.2	1.0 ± 0.5	2.2
Willow	2.5 cm ≤ dbh < 8 cm	0.0 ± 0.0	0.0 ± 0.0	*	73.7 ± 8.5	57.0 ± 9.3	0.9
	dbh ≥ 8 cm	0.0 ± 0.0	0.0 ± 0.0	*	7.0 ± 1.3	5.1 ± 1.2	1.8
Paper birch	2.5 cm ≤ dbh < 8 cm	2.9 ± 1.6	2.1 ± 1.3	5.5	13.5 ± 2.8	12.4 ± 2.6	2.8
	dbh ≥ 8 cm	1.1 ± 0.3	3.6 ± 1.4	3.6	8.2 ± 1.5	9.8 ± 2.0	2.0
Balsam poplar	2.5 cm ≤ dbh < 8 cm	0.0 ± 0.0	0.0 ± 0.0	*	0.4 ± 0.3	0.5 ± 0.3	3.1
	dbh ≥ 8 cm	0.0 ± 0.0	0.0 ± 0.0	*	0.3 ± 0.2	1.8 ± 1.1	0.0
Black spruce	2.5 cm ≤ dbh < 8 cm	55.9 ± 7.3	36.3 ± 6.6	0.0	0.3 ± 0.3	0.0 ± 0.0	2.1
	dbh ≥ 8 cm	8.9 ± 1.4	6.2 ± 1.5	4.4	0.2 ± 0.2	0.0 ± 0.0	0.3
White spruce	2.5 cm ≤ dbh < 8 cm	1.7 ± 0.5	1.3 ± 0.6	6.8	1.0 ± 0.3	2.2 ± 1.2	1.5
	dbh ≥ 8 cm	1.6 ± 0.5	1.9 ± 0.8	7.1	0.5 ± 0.2	0.8 ± 0.3	1.4
Canopy cover		20.5 ± 2.6	17.1 ± 3.9	6.4	25.2 ± 2.4	24.1 ± 3.5	3.0
Surface water cover		12.4 ± 3.3	15.3 ± 3.8	6.9	22.4 ± 3.0	25.0 ± 3.5	2.6
Intercept only				5.1			1.0

<sup>1</sup> For each study area separately, we used univariate logistic regression with a matched pairs design to compare habitat variables between nest areas and paired random areas not used for nesting. We compared the relative fit of models within each study area using Akaike's information criterion adjusted for small sample sizes (AIC<sub>c</sub>) and rescaled as AIC<sub>c</sub> differences ( $\Delta_i$ ; an asterisk indicates that the tree or shrub species occurred at densities to model habitat selection).

<sup>2</sup> Shrub and tree densities are numbers of live and dead stems within 20 x 20-m vegetation plots (0.04 ha). Canopy cover and surface water cover were the percent of 39 points intercepting vegetation > 3 m in height and surface water, respectively.

## Chapter 3

### **Preliminary Estimates of Apparent Adult Survival among Nesting Rusty Blackbirds.**

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*Abstract.* Although the Rusty Blackbird has suffered steep and range-wide population declines, no data are available to determine whether the species suffers from low rates of adult survival. In this study we estimated annual probabilities of apparent adult survival among Rusty Blackbirds nesting on military lands in Alaska from 2007–2009. In Anchorage we captured an average of 21 birds per year and found that adult survival was two-times greater in 2008–2009 ( $\Phi = 0.70 \pm 20$ ) than during the previous year, 2007–2008 ( $\Phi = 0.34 \pm 0.11$ ). Respectively, these rates of survival were similar to stable and declining populations of Common Grackles (*Quiscalus quiscula*) and Red-winged Blackbirds (*Agelaius phoeniceus*) breeding in the contiguous U.S. We were able to detect this annual change in survival in Rusty Blackbirds despite a relatively small sample size and low statistical power (48%) to detect the difference. A modest increase in sample size to 50 captures per year would achieve 90% power to detect this same annual differences in survival. To do so, resighting probabilities for marked birds would need to be as high as in Anchorage ( $p = 0.76 \pm 0.20$ ). Recapture rates, though, were much lower on the Tanana Flats ( $p = 0.17$ ) so special measures need to be taken to increase survey coverage in order to resight marked birds at higher rates. Additional years of sampling are still needed to determine whether populations suffer from chronically low or highly variable rates of annual adult survival, both of which have been linked to population declines in other species of birds.

## INTRODUCTION

The cause of the Rusty Blackbird's long-term and range-wide decline in population size remains unknown (Greenberg et al. 2010) but must be linked to deficits in either birth or death rates. Recent investigations of the survival rates of the eggs and nestlings of Rusty Blackbirds in Alaska (Matsuoka et al. *in review*) and New England (Powell et al. *in review*) indicate that reproductive success among Rusty Blackbirds averages higher than that of other North American blackbird species, is high across all unmanaged sites evaluated in Alaska and New England, but is comparable to other blackbird species when the species nests in stands regenerating from recent timber harvests in New England. Thus there is no clear evidence that deficits in birth rates are closely linked to the species' decline (Matsuoka et al. *in review*). This suggests that deficits in survival among adults or juveniles are likely mechanisms for the species' decline; however, no studies have evaluated these demographic traits among Rusty Blackbirds to date. To address this information gap, we banded and subsequently resighted nesting Rusty Blackbirds on military lands in Alaska from 2007–2009. Here we present our preliminary findings on apparent adult survival rates.

## METHODS

We captured and banded adult Rusty Blackbird from 2007–2009 in 36-mm mesh nylon mist nets placed near active nests that we found among wetlands on the Tanana Flats Training Area of the U.S. Army’s Fort Wainwright (hereafter Tanana Flats) near Fairbanks, Alaska and at Elmendorf Air Force Base and adjacent Fort Richardson near Anchorage, Alaska (hereafter Anchorage). We previously described in detail these study areas and associated habitats and nests (Chapters 1 and 2). Each captured bird was measured, weighed, banded with a unique combination of one aluminum band and three colored leg bands, and then released. In 2007 and 2008 we searched color-marked birds during our systematic surveys of breeding adults and subsequent intensive searches and monitoring of nests (Chapters 1 and 2).

We used a Cormack-Jolly-Seber (CJS) model (Lebreton et al. 1992) in program MARK 5.1 (White and Burnham 1999) to analyze our mark-resighting data and estimate annual rates of apparent adult survival ( $\Phi$ ) corrected for resighting probabilities ( $p$ ). Using the CJS model, we estimate an “apparent” rate of annual adult survival because we could not distinguish those birds that permanently emigrated from our study area from those that actually died. Our estimates of adult survival are consequently conservative (Lebreton et al. 1992). We developed a CJS model of apparent adult survival that pooled years ( $\Phi$ ) and compared the relative fit of this model to one that included the effects of year ( $\Phi_{year}$ ; 1 June 2007–31 May 2008 versus 1 June 2008–31 May 2009). We could not include a covariate for year in the resighting probability because we only had 3 years of data. We compared the relative fit of models using (1) likelihood ratio test based on model deviances and (2) Akaike’s information criterion ( $AIC_c$ ), rescaled as  $AIC_c$  differences ( $\Delta_i$ ), and model probabilities ( $w_i$ ; Burnham and Anderson 2002).

Next, we used our parameter estimates for  $\Phi$  and  $p$  from the model that allowed survival to vary by year and ran 100 simulations with a sin-link function in program MARK to evaluate statistical power to detect annual differences in survival for sample sizes of 10, 20, 30, 50, and 60 birds newly marked each year (Cooch and White 2009). For each of the 100 simulation and samples sizes, we conducted likelihood ratio tests to assess whether the difference in deviances between models with and without year effects was significant ( $\alpha = 0.05$ ). We also calculated the  $AIC_c$  difference between the model with and without year effects for each simulation and sample size. We then calculated as our metric of statistical power, the proportion of the 100 simulations with significant likelihood ratio tests. For the 100 simulations, we also calculated the average  $AIC_c$  differences between models with and without year effects. We present all parameter estimates  $\pm$  SE.

## RESULTS

We captured a total of 55 nesting adults in Anchorage and 33 adults on the Tanana Flats from 2007–2009. The number of new birds that we captured each year in Anchorage declined from 23 birds in 2007 to 20 birds in 2008 to 12 birds in 2009 in Anchorage. The number of new captures was lower on the Tanana Flats (14 birds each in 2008 and 2009), particularly in 2007 when only 5 adults were banded. Of the 43 adults we captured in Anchorage in 2007 and 2008, we resighted 44% in subsequent years. On the Tanana Flats, we only resighted in subsequent years 21% of 19 birds that we banded in 2007 and 2008 (Table 1).

A model of adult survival in Anchorage that included year was better supported by the data than the model without year effects both in terms of the likelihood ratio test ( $\chi^2 = 3.974$ ,  $df = 1$ ,  $P = 0.04$ ) and  $AIC_c$  differences ( $\Delta_i = 1.7$  lower than no effects model; Table 2). The model with year effects was 2.3 times more likely than the model with no effects (Table 2) and indicated adult survival was 2-times greater from 2008–2009 than 2007–2008 (Table 3). We could not estimate adult survival for Rusty Blackbirds on the Tanana Flats because of the small number of birds captured in 2007 and a low resighting probability of 0.167 which was 4.2-times lower than in Anchorage ( $p = 0.76$ ; Table 3).

Our simulations of mark-recapture data from Anchorage indicated that we had only moderate statistical power to detect the observed difference of 0.36 in adult annual survival with the average of 21.5 birds we captured in 2007 and 2008. Of the 100 simulations based on 20 captures a year, only 48% included models with year effects that were significantly better than the models without year effects. On average, models with year effects had  $AIC_c$  values that were 2.5 points better than the model with no effects. We did not reach 90% power to detect the observed difference in annual survival until sample size increased to 50 captures a year (Table 4). With 50 captures each year the models with year effects had averaged  $AIC_c$  values that were 8.7 points better than the models with no effects (Table 4).

## DISCUSSION

We found that the probability of survival for adult Rusty Blackbirds nesting in Anchorage was 2-times greater during 2008–2009 ( $\Phi = 0.70 \pm 0.20$ ) than during the previous year, 2007–2008 ( $\Phi = 0.34 \pm 0.11$ ). Interestingly, the lower rate of annual survival for Rusty Blackbirds was similar to survival rates for declining populations (trend = -2.1% and -2.5% per year,  $P < 0.01$ ; Sauer et al. 2008) of Common Grackles (*Quiscalus quiscula*) in the northeastern ( $\Phi = 0.34 \pm 0.12$ ) and southeastern U.S. ( $\Phi = 0.26 \pm 0.13$ ; Michel et al. 2006), and slightly lower than survival rates reported for declining (trend = -0.9 and -2.0% per year,  $P < 0.01$ ; Sauer et al. 2008) Red-winged Blackbirds (*Agelaius phoeniceus*) in the north-central ( $\Phi = 0.45 \pm 0.12$ ) and northeastern U.S. ( $\Phi = 0.55 \pm 0.06$ ; Michel et al. 2006). Conversely, our higher estimate of adult survival for Rusty Blackbirds was similar to those estimated for more stable populations of Red-winged Blackbirds (trend = -0.7% to 0.3% per year,  $P \geq 0.17$ ; Sauer et al. 2008) breeding in the northwestern ( $\Phi = 0.68 \pm 0.06$ ) and southwestern U.S. ( $\Phi = 0.71 \pm 0.15$ ; Michel et al. 2006).

With only three years of data it is not yet clear whether adult survival rates among Rusty Blackbirds are sufficiently low to cause declines in the Anchorage population. However, the 2-fold change in adult survival over two years indicates that annual survival rates might be expected to be highly variable across longer periods of time. Schmutz (2009) recently analyzed long-term data on annual survival rates for 62 populations of birds and found that increases in the variability of survival rates across years were sufficient to cause population declines in birds even if the mean rate of survival across years did not change overtime. He echoed the argument of Pfister (1998) that natural selection should minimize variability in demographic traits that populations are highly sensitive to, such as survival rates (Schmutz 2009). Thus at least two additional years of survival data are necessary to determine whether chronically low rates of survival or extreme variability in survival rates across years may be linked to declines in Rusty Blackbirds.

We were able to detect the annual difference in survival despite capturing only 21 adult Rusty Blackbirds each year in Anchorage in 2007 and 2008. This was largely due to our relatively high resighting rate ( $p = 0.76$ ) and the rather large difference in survival between the two years. Our ability to detect this difference in annual survival estimates though was somewhat marginal due to low statistical power to detect this trend (48% power). However, our simulations showed that a small increase in sample size to 50 birds captured per year would allow us to achieve 90% power to detect this same difference in annual survival rates. We were able to exceed this sample size in Alaska with additional captures of Rusty Blackbirds on the Tanana Flats ( $n = 14$  birds) and new studies capturing the species on the Yukon Flats National Wildlife Refuge (NWR,  $n = 27$  adults) and the Copper River Delta ( $n = 13$  birds). A new study is also planned for the Tetlin NWR in 2010. The one caveat is that the resighting probability for these other studies will have to be as high in order for a sample size of 50 marked birds per year to achieve 90% power to detect annual differences in survival. Because we found the recapture probability to be quite low on the Tanana Flats ( $p = 0.17$ ), special care will need to be taken to increase the coverage of resighting surveys on the Tanana Flats and any new study areas in Alaska. Although the resighting rate on the Tanana Flats was quite low, additional years of data are needed to determine whether this estimate is an artifact of the small number of birds ( $n = 5$ ) captured in 2007. As we accumulate more data in the future, we will use robust models to compute annual estimates of both survival and recruitment rates (Kendall 2009). This will likely add precision to our annual estimates of survival and help us determine if populations suffer from low rates of recruitment.

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Table 1. Number of birds showing different capture histories in Anchorage and the Tanana Flats, Alaska 2007–2009. For each year, the initial capture or resighting of a bird in a year is denoted by a value of one, the lack of captures or resightings in a year is denoted by a zero.

Description of capture histories	Anchorage				Tanana Flats			
	2007	2008	2009	No. birds	2007	2008	2009	No. birds
Captured 2007, never resighted	1	0	0	16	1	0	0	4
Captured 2007, resighted 2008 and 2009	1	1	1	2	1	1	1	0
Captured 2007, resighted 2008 only	1	1	0	4	1	1	0	0
Captured 2007, resighted 2009 only	1	0	1	1	1	0	1	1
Captured 2008, never resighted	0	1	0	8	0	1	0	11
Captured 2008, resighted 2009	0	1	1	12	0	1	1	3
Captured 2009	0	0	1	12	0	0	1	14
Total				55				33

Table 2. Comparisons of fit between models of apparent adults survival probabilities ( $\Phi$ ), with and without year effects, for Rusty Blackbirds nesting in Anchorage, Alaska 2006–2009.

Model	AIC <sub>c</sub>	$\Delta_i$	$w_i$	No. Parameters	Deviance
$\Phi_{\text{year}}$	76.43	0.00	0.70	3	1.33
$\Phi$	78.13	1.70	0.30	2	5.30

Table 3. Estimates of apparent adult survival ( $\Phi$ ) and resighting probabilities ( $p$ ) for Rusty Blackbirds nesting in Anchorage, Alaska 2007–2009.

Parameter	Estimate	SE	95% confidence interval	
			Lower	Upper
$\Phi_{2007-2008}$	0.34	0.11	0.16	0.58
$\Phi_{2008-2009}$	0.70	0.20	0.26	0.94
$p$	0.76	0.20	0.27	0.96

Table 4. The effects of sample size on statistical power to detect annual differences in apparent adult survival for Rusty Blackbirds nesting in Anchorage, Alaska.

No. captures per year	% power <sup>1</sup>	Average $\Delta_i$ <sup>2</sup>
10	23	0.1
20	48	2.5
30	68	6.6
50	90	8.7
60	94	10.0

<sup>1</sup> Statistical power is defined here as the percentage of 100 simulations that had significant ( $\alpha = 0.05$ ) likelihood ratio tests for models with year effects compared to models without year effects.

<sup>2</sup> Denotes the mean difference in AIC<sub>c</sub> values between models with and without year effects.

## Chapter 4

### **Preliminary Results on Concentrations of Environmental Contaminants in the Eggs of Rusty Blackbirds Nesting in Alaska**

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*Abstract.* We sampled addled eggs and eggs from failed nests of Rusty Blackbirds near Anchorage and Fairbanks, Alaska 2007–2008. In the 13 egg samples, mercury and strontium concentrations approached levels of concern, but other metals and all persistent organic environmental contaminant concentrations did not. With analysis of additional data from samples submitted in 2009, more definitive conclusions can be reached regarding the effects of environmental contaminants in eggs on Rusty Blackbird populations.

#### INTRODUCTION

This interim report contributes to data collected under the project, “Assessing the value of Department of Defense lands in Alaska to a declining species, the Rusty Blackbird”. Populations of this once abundant bird have suffered steep declines, and toxic levels of environmental contaminants are one potential avenue for population reduction through mortality and decreased reproduction. The current report covers contaminants data from eggs collected in 2007–2008 (13 samples); additional samples were submitted in 2009 and are being analyzed.

#### METHODS

Single eggs that failed to hatch, or multiple eggs from nests that were abandoned, were collected opportunistically from study areas on the Tanana Flats Training Area of Fort Wainwright near Fairbanks (Fairbanks) and Fort Richardson and Elmendorf Air Force Base near Anchorage (Anchorage). For each year, three or four samples each were analyzed from the Fairbanks and Anchorage study areas. A “sample” consists of eggs from one nest, as eggs within a clutch are not independent samples. Eggs were refrigerated until opened in a laboratory using chemically clean instruments, and contents were placed in chemically clean jars (I-Chem Series 300 or equivalent). Samples were frozen at -40 °C until shipped overnight on dry ice to the analytical laboratory. Nineteen trace elements (metals) and over 20 persistent organic pollutants were analyzed in egg contents using standard methods at U.S. Fish and Wildlife Service-contracted analytical laboratories.

#### RESULTS AND DISCUSSION

We discuss results of analytes that have established toxicity concerns in avian eggs including cadmium (Cd), lead (Pb), mercury (Hg), selenium (Se), strontium (Sr), polychlorinated biphenyls

(PCBs), dichlorodiphenyltrichloroethane (DDT) and its metabolites, particularly DDE, and dieldrin, hexachlorobenzene (HCB), and mirex. Data are reported in parts per million (ppm), in either dry weight (dw) or wet weight (ww), depending upon the analyte. *These results should be considered preliminary.* A complete statistical analysis of all analytes will be completed upon receipt of data from samples submitted in 2009. These data are expected to arrive by March, 2010.

Cadmium was below detection limit (dl) of 0.1 ppm dw in all but one sample, and that sample was only slightly above the dl (07FAI01, 0.3 ppm dw), so Cd concentrations were very low. The average Pb concentration was 0.81 ppm dw (dl 0.2 ppm dw), with an outlier from Fairbanks (2007, 07FAI02, 4.8 ppm dw). This level is considered elevated and would suggest toxic levels of lead in the laying female. However, it is difficult to base conclusions on one sample; additional corroborative data from the area would be necessary to indicate that Pb concentrations are of concern for Rusty Blackbirds. A Se-toxicity threshold for avian reproductive effects is approximately 3 ppm ww (Heinz 1996), but blackbirds eggs average only 0.73 ppm ww.

Mercury (dl = 0.02 ppm ww) averaged 0.4 ppm ww. These slightly elevated concentrations approached a toxicity threshold of 0.5 ppm (Thompson 1996). There was no distinction between Fairbanks and Anchorage samples in mercury concentrations ( $\bar{x} = 0.04$  for both,  $n = 7$  for Anchorage,  $n = 6$  for Fairbanks). Mercury causes avian embryotoxicity, and could therefore have effects on Rusty Blackbird populations.

The average Sr concentration was 5.97 ppm dw (dl = 0.200), with an outlier from Anchorage (2007, 07ANC02) that had 25.1 ppm dw. This was above the 11.3 ppm associated with hepatic oxidative stress in pipping Black-crowned Night Herons (*Nycticorax nycticorax*; Rattner et al. 2000). Concentrations around 10 ppm were potentially associated with decreased hatching success in passerines (Mora 2003); approximately 25 ppm were associated with significantly decreased eggshell thickness in Lesser Scaup (*Aythya affinis*) breeding in Alaska (Matz and Rocque 2007). Levels and effects of Sr concentrations in avian embryos are not widely studied; Matz and Rocque (2007) found a significant correlation between Sr concentrations in egg contents and eggshell thickness in Lesser Scaup in a population with low reproductive success.

Polychlorinated biphenyls were widely used in industrial applications requiring insulating capacity, including transformers. They are effective avian embryotoxins and persistent in the environment. Analysis of PCBs varies in expense and precision. Measurement methods range from precise measurement of PCB congeners, the specific chemical structures that vary in toxicity, to a generalized measurement of total PCBs. Precise (and expensive) congener analysis is warranted if PCB concentrations are unknown and there are population declines, as the embryotoxic effects of PCBs can be severe. In 2007–2008, we measured PCB congeners in RUBL eggs, with particular focus on the most toxic congeners to avian embryos, PCBs 81, 77, 126, 169, 105, 114, 118, 123, 156, 157, 167, and 189 (Van den Berg et al. 1998). Most PCB congeners were below detection limits in most samples, and PCBs 77 and 81, the most toxic, were not detected in any samples.

The persistent organochlorine insecticide DDT was widely used for mosquito control in Alaska, especially around human population centers. Of particular concern is the metabolite p,p'-DDE,

which caused eggshell thinning leading to decreased reproduction and population crashes in piscivorous birds in the 1960s–1970s. The average p,p'-DDE concentration was 0.13 ppm ww, with no outliers. This concentration is well below those associated with population declines in other avian species, which are generally an order of magnitude greater (e.g., above 1 ppm ww; Blus 1996). Both HCB and mirex, other persistent organic pollutants of concern for avian reproduction, were detected in most eggs (average 0.002 and 0.003 ppm ww, respectively), but at levels orders of magnitude below reproductive toxicity thresholds (e.g., above 10 ppm ww; Wiemeyer 1996).

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## Appendix 1

### **Environmental Mercury Loads may be a Contributing Stressor to Declining Rusty Blackbird Populations.**

Edmonds, S. T., D. C. Evers, N. J. O'Driscoll, C. Mettke-Hoffman, and D. Cristol.

*Abstract.* The Rusty Blackbird (*Euphagus carolinus*; RUBL) is the fastest declining passerine species in North American yet limited study has made it hard to explain the cause of its decline. This study examined blood and feather mercury (Hg) concentrations among Rusty Blackbirds on their breeding grounds in Alaska, New England, and Maritime Provinces of Canada and on their wintering grounds in the south-central and southeastern U.S. Blood Hg concentrations among Rusty Blackbirds breeding in New England and Maritime Provinces [ $\bar{x} = 1.06 \pm 0.54$  (SD)  $\mu\text{g g}^{-1}$ ,  $n = 59$ ] were over three-times greater than in Alaska ( $\bar{x} = 0.31 \pm 0.24 \mu\text{g g}^{-1}$ ,  $n = 107$ ) and were comparable to levels found among Red-winged Blackbirds (*Agelaius phoeniceus*) breeding at a site known to be contaminated with industrial Hg, though feather Hg concentrations were over 20-times greater in Rusty than Red-winged Blackbirds. Hg concentration in Alaska were highest in the Tanana River region ( $\bar{x} = 0.59 \pm 0.24 \mu\text{g g}^{-1}$ ) and on the Eagle River Flats in the South-central region. Wintering populations in the southeastern U.S. had blood Hg concentrations ( $\bar{x} = 0.17 \pm 0.23 \mu\text{g g}^{-1}$ ,  $n = 144$ ) that were lower than breeding populations but four-times higher than those found in wintering birds in the south-central U.S. ( $\bar{x} = 0.04 \pm 0.04 \mu\text{g g}^{-1}$ ,  $n = 92$ ). The blood and feather Hg concentrations that we report for Rusty Blackbirds breeding areas in New England and the Maritime Provinces are the highest known for any wild population of passerine not associated with a point source of mercury contamination. These concentrations are high enough to cause reproductive failures in other closely related species and may be contributing to the continued decline of the Rusty Blackbird in its eastern range.

Table 1. Mean concentrations  $\pm$  SD ( $n$ ) of total mercury in the blood ( $\mu\text{g/g}$ , ww) and feathers ( $\mu\text{g/g}$  fw) of breeding and winter a) Rusty Blackbirds, b) Red-winged Blackbirds, and c) Common Grackles by state, province, and region. Regions in Alaska that included samples from DoD lands are included in bold.

Species/Region (season)	State or Province	Blood	Feathers
a) Rusty Blackbird			
Northeast (breeding)	Maine	0.75 $\pm$ 0.30 (15)	4.08 (1)
	New Brunswick	1.28 $\pm$ 0.43 (7)	22.19 $\pm$ 13.98 (7)
	New Hampshire	1.01 $\pm$ 0.42 (20)	19.99 $\pm$ 11.89 (20)
	Nova Scotia	1.46 $\pm$ 1.00 (8)	18.56 $\pm$ 15.34 (8)
	Vermont	1.17 $\pm$ 0.30 (9)	19.22 $\pm$ 13.83 (9)
	Total	1.06 $\pm$ 0.54 (59)	19.57 $\pm$ 12.91 (45)
Southeast (winter)	North Carolina	(0)	3.57 $\pm$ 0.84 (5)
	South Carolina	0.16 $\pm$ 0.05 (64)	4.72 $\pm$ 4.56 (14)
	Virginia	0.17 $\pm$ 0.30 (80)	3.44 $\pm$ 2.49 (94)
	Total	0.17 $\pm$ 0.23 (144)	3.61 $\pm$ 2.79 (113)
Eastern	Eastern total		8.15 $\pm$ 10.22 (158)
Alaska (breeding)	Yukon Flats	0.17 $\pm$ 0.12 (25)	0.42 (1)

Species/Region (season)	State or Province	Blood	Feathers
	<b>Tanana River<sup>1</sup></b>	<b>0.59 ± 0.24 (25)</b>	<b>2.04 ± 1.65 (3)</b>
	<b>South-central Alaska<sup>2</sup></b>	<b>0.28 ± 0.20 (48)</b>	<b>(0)</b>
	Western Alaska	0.15 ± 0.11 (9)	3.45 ± 2.02 (10)
	Total	0.31 ± 0.24 (107)	2.93 ± 2.03 (14)
South-central (winter)	Arkansas	0.01 ± 0.004 (7)	1.87 ± 0.51 (7)
	Louisiana	(0)	2.68 ± 3.42 (14)
	Mississippi	0.04 ± 0.04 (85)	3.58 ± 3.13 (51)
	Total	0.04 ± 0.04 (92)	3.24 ± 3.06 (72)
Western	Western total		3.19 ± 2.91 (86)
Overall	Overall total	(402)	6.40 ± 8.72 (244)
b) Red-winged Blackbird	Maine	0.20 (1)	13.75 (1)
Northeast (breeding)	Massachusetts	0.60 ± 0.46 (14)	1.28 ± 2.59 (13)
	New Brunswick	0.42 ± 0.21 (5)	0.35 ± 0.06 (5)
	New Hampshire	0.58 ± 0.26 (2)	0.53 ± 0.30 (2)
	New York	0.28 ± 0.14 (27)	0.59 ± 0.94 (19)
	Nova Scotia	0.12 (1)	0.21 (1)
	Northeast total	0.39 ± 0.31 (50)	1.08 ± 2.58 (40)
Southeast (winter)	Virginia	0.01 ± 1.83 (4)	1.83 ± 1.75 (4)
Eastern	Eastern total	(54)	1.15 ± 2.51 (44)
Contaminated	Contaminated total	1.88 ± 2.97 (20)	0.82 ± 0.62 (18)
c) Common Grackle	New Hampshire	0.23 (1)	0.85 (1)
Eastern (breeding)	Nova Scotia	0.23 (1)	0.82 (1)
	Virginia	0.13 ± 0.03 (3)	(0)
	Breeding total	0.17 ± 0.06 (5)	0.83 ± 0.02 (2)

<sup>1</sup> Samples from the Tanana River region in Alaska were taken from birds nesting on the Tanana Flats Training Area of Fort Wainwright and Tetlin National Wildlife Refuge.

<sup>2</sup> Sample from the South-central region in Alaska were taken from birds nesting in Anchorage, Elmendorf Air Force Base, Fort Richardson, and Copper River Delta.

## Appendix 2

**Prevalence of Hematozoa among Breeding and Wintering Rusty Blackbirds**

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*Abstract.* The Rusty Blackbird (*Euphagus carolinus*) has declined precipitously over the past several decades. Blood samples were collected over a three-year period from breeding birds in Alaska and Maine and from wintering birds in Mississippi and Arkansas to determine exposures rates to blood parasites. The prevalence (percent infected) among Alaska birds was 33% and 57% for 2007 and 2008 respectively, for an overall prevalence of 47% of 36 birds. Blood parasites were found among 67% of 12 Rusty Blackbirds sampled in Maine in 2007.

*Leucocytozoan*, *Plasmodium*, and *Trypanosoma* were identified among the breeding birds sampled. The prevalence of blood parasites in Rusty Blackbirds was previously known from only a single report of 87% of 23 breeding birds in Newfoundland and Ontario. Overall prevalence of blood parasites in Mississippi and Arkansas during the winter was 49% over three years. *Leucocytozoan* was the most commonly encountered parasite during the winter ( $n = 62$  birds), followed by *Haemoproteus* ( $n = 5$ ), microfilaria sp. ( $n = 2$ ), *Trypanosoma* ( $n = 2$ ), and *Plasmodium* ( $n = 1$ ). The prevalence of haematozoa among wintering Rusty Blackbirds was much higher than expected because winter is generally a time when there are few transmissions and blood parasites are absent from the peripheral circulation in most birds. This might indicate that a non-seasonal relapse occurred among wintering birds; possibly due to high levels of stress which are known to lower the immune response and trigger non-seasonal relapses. Hematozoa infections typically do not typically result in direct mortality but may have indirect effects on birds mounting an immune response to the infection. Thus, we recommend that future studies examine the indirect effects of hematozoa infections on wintering Rusty Blackbirds.