Nest success and nest site selection of shorebirds in North Dakota

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NEST SUCCESS AND NEST SITE SELECTION OF SHOREBIRDS IN NORTH DAKOTA

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ABSTRACT

I compared nest success estimates for both shorebirds and Sharp-tailed Grouse between controls and 36 square-mile blocks that were trapped for intermediate mammalian predators. I also investigated shorebird nest site selection by comparing vegetation visual obstruction and species composition between nest sites and the surrounding field. Nest success (Mayfield estimate ± SE) was not different between trapped and control blocks for shorebirds (trap: 50.8% ± 6.3%; control: 69.1% ± 17.5%) or Sharp-tailed Grouse (trap: 61.3% ± 8.3%; control: 48.7% ± 10.0%). This indicates that trapping intermediate mammalian predators is not an efficient method of increasing shorebird or Sharp-tailed Grouse nest success. Regardless of the surrounding habitat type, shorebird nest sites were located in characteristic vegetation depending on species. Common Snipe preferred nest sites to be covered by native vegetation that obstructed vision below 21cm. Wilson's Phalarope also preferred native vegetation, however they nested in vegetation obstructing vision less than 16cm. Upland Sandpipers showed little preference for vegetation species composition, although nest sites were typically found in vegetation obstructing vision less than 21cm. These results indicate that useful shorebird habitat includes relatively sparse, native vegetation.

INTRODUCTION

In recent decades the decline in abundance of grassland nesting birds has been more severe than for any other group of birds in North America (Knopf 1992, Samson and Knopf 1994, Wilson et al. 2005). Included in this assemblage of species are a set of mid-latitude nesting shorebirds such as American Avocet (*Recurvirostra americana*), Common Snipe (*Gallinago gallinago*), Killdeer (*Charadrius vociferus*), Marbled Godwit (*Limosa fedoa*), Piping Plover (*Charadrius melodus*), Upland Sandpiper (*Bartramia longicauda*), Willet (*Catoptrophorus semipalmatus*), and Wilson's Phalarope (*Phalaropus tricolor*), which all nest in parts of eastern North Dakota. Several of these species, especially the Piping Plover, have shown substantial population declines over the last century (Howe et al. 1989, Johnson and Schwartz 1993, Houston 1999, Morrison et al. 2001).

The major cause of population declines in grassland nesting bird species is the conversion of grassland to cultivated cropland (Krebs et al. 1999). This transformation has resulted in a fragmented landscape in many regions of the North American Great Plains, including much of northeastern North Dakota. While habitat fragmentation itself is often relatively obvious, there are numerous invisible effects experienced by the inhabitants of such landscapes, including decreased migration, genetic variability, and population abundances (Hooftman et al. 2004).

Although eastern North Dakota has been drastically altered by human activities, some native and restored tracts of grassland exist. The management of these grasslands has become increasingly important for grassland nesting birds as the available grassland habitat shrinks (Davis 2005). As a crucial consideration of wildlife management plans, habitat requirements of certain species must be identified. To aid in the effectiveness and efficiency of grassland restoration and management, my project was concerned with determining nest-site selection

criteria for shorebird species breeding in eastern North Dakota. Shorebirds have been shown to actively select nest sites, often based on vegetation structure, rather than placing them at random (Colwell and Oring 1990). I quantified vegetation density and canopy coverage by plant species at the nest and in the surrounding field to identify preferences shown for nest sites at both the microhabitat and field levels.

A second result of fragmentation is that habitat edges increase as patch size decreases. Edges are preferentially used by many mammalian nest predators including red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*), which should be expected to increase predation rates on ground nesting bird species (Paton 1994). While abundance declines in some species of grassland nesting birds have been attributed to habitat loss (Greenwood et al. 1995, Beauchamp et al. 1996), the trend in declining abundance of some shorebird species also may be related to nest predation (Kirsh and Higgins 1976, Gratto-Trevor et al. 1983, Bowen and Kruse 1993, Helmers and Gratto-Trevor 1996).

In response to increased risk of predation upon ground nesting bird species, interest has been generated for management techniques designed to decrease nest predator abundance. In the 1960s and 1970s, numerous studies where toxicants were used to reduce waterfowl nest predator abundances resulted in significantly increased nest success rates in waterfowl species (Balser et al. 1968, Lynch 1972, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980). After the use of toxicants became illegal, research turned to the use of trapping to remove predators. In the North Dakota drift prairie region, predator removal effectively doubled waterfowl nest success in study areas (Garrettson et al. 1996, Hoff 1999, Garrettson and Rohwer 2001, Chodachek and Chamberlain 2006).

Songbirds also have received modest attention in predator removal research, although nest success rates appear to remain unchanged for grassland nesting passerines (Dion et al. 1999, Dion et al. 2000). Interestingly, while the overall level of songbird nest success was not affected by predator trapping, the primary agents of nest failure shifted. The usual primary cause of failure by intermediate mammalian predation (red fox, raccoon, and striped skunk) was replaced by small mammals, such as mice and ground squirrels, which appear to increase when medium sized mammals were trapped (Dion et al. 1999, Adkins 2003). This conclusion is consistent with predictions made in situations of trophic cascade, in which individuals of lower level trophic levels are released from higher order predation risk (Henke and Bryant 1999). The reduction of top predators in much of the Northern Great Plains has resulted in mesopredator release (Elmhagen and Rushton 2007). When intermediate predators are removed, we may expect to observe a similar small predator release. If such a situation exists in areas of intermediate predator reduction, then benefits of trapping should not be expected to benefit all bird species equally. Ground nesting bird species that lay relatively small eggs (such as shorebirds) may not experience increases in nest success similar to waterfowl, due to increased predation pressure from small mammals.

I investigated the effects of medium-sized mammalian predator removal on nest success rates in shorebirds and other species of ground nesting birds. Specifically, I examined whether predator removal increases nest success as is common for waterfowl species, decreases nest success as predicted in situations of trophic cascade, or remains unchanged. Nest success was estimated using two methods: the Johnson-adjusted Mayfield method (Johnson 1979), and the logistic exposure method (Shaffer 2004). Studies of nest success typically use the Johnson-adjusted Mayfield method and require an estimate of nest initiation date for each nest (Johnson

1979). Logistic exposure nest success was estimated because methods used to estimate nest initiation date for shorebirds are imprecise.

Initiation date is generally calculated by backdating from the date of discovery, and is the sum of incubation period and number of eggs in the nest at discovery. Incubation stage in waterfowl research is commonly estimated by the candling method, in which embryos are observed through the surrounding semi-transparent eggshell when held in front of a bright light (Weller 1956). However, because the opacity of many ground nesting bird eggs is too great to permit candling, another method is required in the determination of incubation stage. Egg flotation (Westerskov 1950) is commonly used in ornithological research when candling is not possible. Although numerous studies make use of egg flotation, there is little published data outlining its use or relationship between flotation stage to egg age, especially for shorebird species (Westerskov 1950, Hays and LeCroy 1971). The final objective of my research is to provide a means for estimating incubation stage of ground nesting bird eggs through the egg flotation method.

METHODS

<u>Study Timeline</u>

Nests were located between May 1 and June 30 in both 2005 and 2006. Nest monitoring continued into July as long as nests were active. Finally, vegetation identification occurred in late July and early August.

<u>Study Site</u>

In 2005, the study site consists of eleven 36 square-mile blocks (twelve in 2006), located within the Devils Lake Wetland Management District in northeastern North Dakota. Intermediate-sized mammalian predators were removed by professional trappers on seven treatment blocks (eight in 2006), whereas four blocks served as controls and were not managed for predators. Within each treatment block, nest searching was conducted on ten 80-acre plots that were randomly selected from land on which landowner permission was secured. In each control block, five 160-acre plots were similarly chosen. Differences in plot size between trap and control blocks were dictated by logistics. Additionally, nest searching was conducted on randomly selected plots located within three miles of the treatment blocks, stratified by distance from block, as part of another graduate project. Waterfowl Production Areas outside of blocks, as well as areas outside plots within the treatment blocks, were searched in order to supplement the sample size.

Predator removal was conducted annually by professional trappers beginning March 1–15 and continuing through July 1–15. Trapping effort was focused on medium-sized mammalian predators, especially red fox, raccoon, and striped skunk. The distribution of traps is determined by the trapper, although trap placement is restricted to land within the boundaries of the treatment block. Predators are assumed to be removed to a similar level between blocks, as

identical financial incentives are offered to trappers based on waterfowl nest success within the blocks.

Data Collection

Nests were located using a modified chain drag method, in which a chain approximately 50m in length is secured and systematically dragged between two all-terrain vehicles over the entire searchable area of the field (Klett et al. 1986). Nests were marked by a 3mm diameter orange rod adjacent to the nest bowl and a numbered white wooden lathe 10m north of the nest.

For each nest we recorded: species, search method (either chain drag or incidental), cause of flush, geographic coordinates, date, time, hen status, nest status, number of eggs, and flotation stage of the nest. If the nest was no longer active when visited, nest fate, cause of fate, and number of unhatched eggs were recorded. Nests were visited on an 8-day rotation.

Egg Flotation and Nest Success

Eggs were floated to determine incubation stage of eggs in the nest. Typically, as egg age increases, they exhibit the following pattern when immersed in water: they first sink with the long axis parallel to bottom, gradually tilting upward, then rest on bottom with long axis perpendicular to bottom, followed by floating with long axis perpendicular to surface, and gradually float higher with the long axis rotating more parallel to surface (Westerskov 1950).

Egg flotation data for Piping Plover, Willet, Marbled Godwit (C.L. Gratto-Trevor unpublished data), Killdeer (S. Fellows unpublished data), Semipalmated Sandpiper (B. McCaffery unpublished data), and Common Tern (Hays and LeCroy 1971) were combined in an attempt to characterize general flotation behavior of eggs across species. From these, I classified incubation stage as outlined in Figure 1, which yielded categories that would be useful for analysis, yet practical to estimate visually in the field. Incubation days could be assigned to

recorded incubation stages by backdating and using published incubation period data (Higgins and Kirsch 1975, Howe 1982, Colwell and Oring 1988, Robinson et al. 1997, Mueller 1999, Gratto-Trevor 2000, Jackson and Jackson 2000), from nests with a known hatch date and projecting from laying-stage nests (Fig. 2).

Figure 2 was constructed from data collected from Wilson's Phalaropes and Upland Sandpipers nests, the most commonly found shorebirds, which also have similar incubation periods of 23 days. Mean values from Figure 2 were used in Mayfield nest success estimates. Incubation days for other species were scaled in proportion to values in Figure 2.

Mayfield nest success estimates were calculated with the formula (from Klett et al. 1986):

$$P = [1 - (N_u/E)]^h$$

where N_u is number of unsuccessful nests, E is total exposure days, and h is mean length of laying plus incubation (27 for shorebirds, 34 for sharp-tailed grouse). N_u/E represents daily mortality rate, whereas $1 - (N_u/E)$ is the daily survival rate (DSR). Nest success is finally estimated by exponentiating the DSR to the number of days a typical nest is exposed to predation (h).

Nest success also was estimated using the logistic exposure method (Shaffer 2004). This method uses a generalized linear model to estimate parameters used to calculate DSR. Generalized linear models consist of three components: 1) a random component designating the probability distribution of the response; 2) a systematic component specifying the explanatory variables chosen; and, 3) a link function relating the systematic and random components (Nelder and Wedderburn 1972). In the logistic exposure method, the random component is the binomial distribution. The systematic component of the model is:

$$[e^{\eta}/(1+ e^{\eta})]^t$$

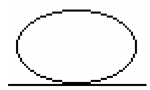
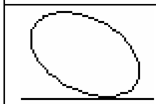
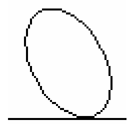
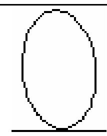
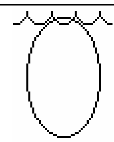
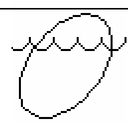
	Stage	Angle to Horizontal
	1	0º – 9º (on bottom)
	2	10º – 44º (on bottom)
	3	45º – 79º (on bottom)
	4	80º – 90º (on bottom)
	5	90º (at surface)
	6	60º – 90º (above surface)
	7	<60º (above surface)

Figure 1. Egg flotation guide, after Westerskov 1950. Eggs were classified into one of seven stages when floated.

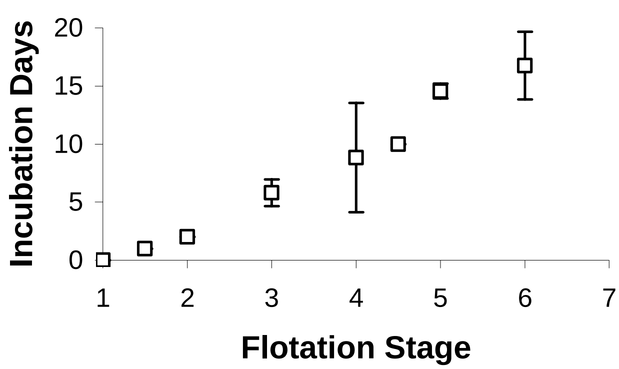


Figure 2. Relationship between flotation stage and incubation days (mean ± 95% C.I.).

where η is the linear combination $\beta_0 + \beta_1 x$ in which βs are calculated by statistical software, and t is the length of an observation interval. Based on the logistic regression link function, the link function for the logistic exposure model is:

$$\ln[(\theta^{1/t})/(1 - \theta^{1/t})]$$

where t is the length of an observation interval, and θ is the DSR^t.

Once η is estimated, DSR is calculated by $e^{\eta}/(1+ e^{\eta})$. As in Mayfield estimation, logistic exposure nest success is estimated by exponentiating DSR to the number of days a typical nest is exposed to predation.

Vegetation Data Collection

Habitat measurements also were taken at each shorebird nest, and at five random locations in the same field. Visual obstruction was measured at the nest (or center point for the 5 random locations) and 1m from the nest/center point in each cardinal direction (Robel et al. 1970). Measurements at the nest and 1m from the nest were not significantly different in 2005 (see Figure 6), so measurements were not recorded 1m from nests in 2006. Nest and associated random measurements were taken on the same day the nest was found to account for differences in vegetation height and density through time.

Using a modified Daubenmire method (Daubenmire 1959), I identified plant species within a $1m^2$ plot centered on the nest and classified them according to canopy cover into the following percentage categories: 0–5%, 5–25%, 25–50%, 50–75%, 75–95%, and 95–100%. I also measured organic litter depth, which I defined as the distance between the upper surface of dead and downed vegetation and the top of the soil. These measurements were delayed until after nest termination in the interest of minimizing nest disturbance, as change in species

composition, canopy coverage, and litter depth throughout the season is assumed to be negligible.

Statistical Analyses

I used analysis of variance to compare vegetation density and composition at nests, 1m from nests, and at random locations in the surrounding field. I used *t*-tests to compare nest success on trapped vs. control blocks, and between habitat types.

All results are reported as mean ± 1 standard error. Mayfield and logistic-exposure nest success estimates are denoted "M" and "L", respectively.

RESULTS

I found 577 nests of ground nesting birds (Tables 1 and 2; 273 nests in 2005, and 304 nests in 2006). Of these, 315 were shorebird nests (Tables 1 and 2; 139 nests in 2005, and 176 nests in 2006). Nests found on trapped and control blocks were included in vegetation and nest success analysis, whereas those discovered outside of blocks were used only for vegetation analysis.

Shorebird nest success was not different between control (M: 69.1% ± 17.5%; L = 77.5% ± 9.8%) and trapped blocks (M: 50.8% ± 6.3%; L: 54.6% ± 6.5%) when all habitats and years were combined (M: Tables 3 – 6, t = 1.45, df = 18, *P* = 0.166; L: Tables 7 – 10, t = 1.50, df = 18, *P* = 0.152). Likewise, there was no difference between the success of shorebird nests in dense nesting cover (DNC) habitats in control (M: 69.1% ± 12.9%; L: 73.2% ± 12.2%) and trapped blocks (M: 63.7% ± 6.8%, L: 66.5% ± 6.4%) (M: Tables 3 – 6, t = 0.38, df = 19, *P* = 0.712; L: Tables 7 – 10, t = 0.48, df = 19, *P* = 0.635). Nest success of shorebirds in pastures in control and trapped blocks was not compared, as no shorebird nests were found in pastures on control blocks. Overall, nest success was higher for shorebirds nesting in DNC (M: 65.1% ± 5.7%; L: 68.2% ± 5.6%) than for shorebirds nesting in pasture (M: 37.9% ± 6.4%; L: 41.6 ± 6.2%) (M: Tables 3 – 6, t = 3.17, df = 27, *P* = 0.004; L: Tables 7 – 10, t = 3.21, df = 27, *P* = 0.004). There were no significant year effects for either treatment or habitat. Finally, Sharp-tailed Grouse nest success did not significantly differ between control (M: 48.7% ± 10.0%; L: 53.8% ± 8.8%) and trapped blocks (M: 61.3% ± 8.3%; L: 70.2% ± 7.3%) (M: Tables 3 – 6, t = 0.97, df = 20, *P* = 0.346; L: Tables 7 – 10, t = 1.43, df = 20, *P* = 0.171). Habitats were not separated for Sharp-tailed Grouse, as nests were found almost exclusively in fields dominated by DNC.

Table 1. Number of shorebird and other ground nesting bird nests found in 2005 in northeastern North Dakota.

	Shorebirds								Other Ground Nesting Birds								
Trapped Blocks	American Avocet	Common Snipe	Killdeer	Marbled Godwit	Upland Sandpiper	Willet	Wilson's Phalarope	Shorebird Total	American Bittern	Mourning Dove	Northern Harrier	Virginia Rail	Short-eared Owl	Sharp-tailed Grouse	Wild Turkey	Non-shorebird Total	Block Total
Cando	0	4	1	1	3	0	9	18	0	0	6	0	0	5	1	12	30
Harlow	2	2	3	0	3	1	15	26	2	3	3	0	0	2	0	10	36
McVille	0	1	0	0	2	0	4	7	1	1	0	1	0	2	0	5	12
Minnewaukan	0	8	2	0	11	0	5	26	1	5	1	0	0	10	0	17	43
Pleasant Lake	0	2	1	0	4	3	4	14	0	2	2	0	1	1	0	6	20
Rolla	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2	2
Whitman	0	2	3	0	1	0	5	11	1	4	1	0	0	3	0	9	20
Total	2	19	10	1	24	4	42	102	5	16	13	1	1	24	1	61	163
Control Blocks																	
Calio	0	0	1	0	9	0	3	13	1	0	2	0	0	2	0	5	18
Church's Ferry	0	0	0	0	5	0	0	5	1	0	1	0	0	7	1	10	15
Crary	0	1	1	0	1	0	0	3	3	0	1	0	0	6	0	10	13
Leeds	0	0	0	0	8	0	0	8	0	1	0	0	0	2	0	3	11
Total	0	1	2	0	23	0	3	29	5	1	4	0	0	17	1	28	57
Outside Blocks																	
Cando	0	0	0	0	0	0	0	0	0	3	0	0	0	4	0	7	7
Harlow	0	2	0	0	1	0	1	4	0	3	1	0	0	11	0	15	19
McVille	0	0	0	0	0	0	0	0	2	1	1	0	1	1	0	6	6
Pleasant Lake	0	0	0	0	1	1	1	3	0	0	3	0	0	4	0	7	10
Whitman	0	1	0	0	0	0	0	1	0	0	2	0	0	8	0	10	11
Total	0	3	0	0	2	1	2	8	2	7	7	0	1	28	0	45	53
Species Total	2	23	12	1	49	5	47	139	12	24	24	1	2	69	2	134	273

Table 2. Number of shorebird and other ground nesting bird nests found in 2006 in northeastern North Dakota.

	Shorebirds								Other Ground Nesting Birds						
Trapped Blocks	American Avocet	Common Snipe	Killdeer	Piping Plover	Upland Sandpiper	Willet	Wilson's Phalarope	Shorebird Total	American Bittern	Mourning Dove	Northen Harrier	Canada Goose	Sharp-tailed Grouse	Non-shorebird Total	Block Total
Bowden	0	0	0	0	0	0	0	0	0	0	2	0	2	4	4
Cando	0	9	0	0	1	1	19	30	0	0	2	0	8	10	40
Harlow	1	3	1	0	4	0	21	30	1	1	1	1	3	7	37
McVille	0	4	1	0	1	0	0	6	0	0	0	0	4	4	10
Minnewaukan	0	2	0	0	12	0	0	14	0	4	3	0	12	19	33
Pleasant Lake	0	5	3	1	5	1	32	47	0	0	0	0	1	1	48
Rock Lake	0	2	0	0	0	0	0	2	0	0	0	0	0	0	2
Whitman	0	1	0	0	0	0	0	1	2	2	0	0	0	4	5
Total	1	26	5	1	23	2	72	130	3	7	8	1	30	49	179
Control Blocks															
Calio	0	0	0	0	1	0	1	2	2	2	2	0	3	9	11
Courtenay	0	0	0	0	3	0	0	3	0	0	1	0	7	8	11
Crary	0	0	0	0	0	0	0	0	1	0	3	0	5	9	9
Leeds	0	0	0	0	4	0	1	5	3	0	0	0	6	9	14
Total	0	0	0	0	8	0	2	10	6	2	6	0	21	35	45
Outside Blocks															
Bowden	0	0	0	0	0	0	0	0	0	0	6	0	3	9	9
Cando	0	0	0	0	0	0	1	1	0	0	0	0	1	1	2
Harlow	0	2	3	0	1	0	10	16	1	2	1	0	14	18	34
Lone Tree WPA	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
McVille	0	0	0	0	0	0	7	7	0	2	1	0	2	5	12
Melass WPA	0	2	2	0	2	0	3	9	0	0	0	0	0	0	9
Tweten WPA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Whitman	0	1	0	0	0	0	2	3	0	4	0	0	5	9	12
Total	0	5	5	0	3	0	23	36	1	8	9	0	26	44	80
Species Total	1	31	10	1	34	2	97	176	10	17	23	1	77	128	304

Table 3. Mayfield nest success for 2005 on trapped blocks, by species group and habitat type. Lower and upper CI indicate lower and upper 95% confidence interval limits, as in Klett et al. (1986). Mean Mayfield estimates and corresponding confidence limits were calculated after grouping by block.

Block	Group	Habitat	Mayfield Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Cando	Shorebird	All	77.8	54.4	110.7	18
	Shorebird	DNC	76.5	52.3	111.4	17
	Shorebird	Pasture	100.0	100.0	100.0	1
	STGR	All	56.7	17.9	173.2	5
Harlow	Shorebird	All	3.2	0.6	14.9	26
	Shorebird	DNC	100.0	100.0	100.0	2
	Shorebird	Pasture	1.3	0.2	8.7	24
	STGR	All	33.9	3.6	276.2	2
McVille	Shorebird	All	100.0	100.0	100.0	7
	Shorebird	DNC	100.0	100.0	100.0	7
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	24.3	1.3	368.0	2
Minnewaukan	Shorebird	All	68.4	46.6	99.7	26
	Shorebird	DNC	84.5	60.1	118.1	12
	Shorebird	Pasture	51.6	23.8	109.7	14
	STGR	All	52.6	24.8	109.6	10
Pleasant Lake	Shorebird	All	52.0	26.8	99.2	14
	Shorebird	DNC	69.6	33.4	142.3	6
	Shorebird	Pasture	39.9	13.5	112.9	8
	STGR	All	100.0	100.0	100.0	1
Rolla	Shorebird	All	n/a	n/a	n/a	0
	Shorebird	DNC	n/a	n/a	n/a	0
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	1
Whitman	Shorebird	All	33.1	12.1	87.4	11
	Shorebird	DNC	33.1	12.1	87.4	11
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	3
Mean	Shorebird	All	49.6	13.5	85.6	102
	Shorebird	DNC	72.6	47.2	97.6	55
	Shorebird	Pasture	25.0	-22.1	72.0	47
	STGR	All	59.4	36.6	82.2	24

STGR = Sharp-tailed Grouse

Table 4. Mayfield nest success for 2006 on trapped blocks, by species group and habitat type. Lower and upper CI indicate lower and upper 95% confidence interval limits, as in Klett et al. (1986). Mean Mayfield estimates and corresponding confidence limits were calculated after grouping by block.

Block	Group	Habitat	Mayfield Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Bowden	Shorebird	All	n/a	n/a	n/a	0
	Shorebird	DNC	n/a	n/a	n/a	0
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	2
Cando	Shorebird	All	49.0	31.7	75.0	30
	Shorebird	DNC	47.8	30.5	74.3	29
	Shorebird	Pasture	100.0	100.0	100.0	1
	STGR	All	46.6	15.5	134.9	8
Harlow	Shorebird	All	50.9	32.3	79.5	30
	Shorebird	DNC	100.0	100.0	100.0	1
	Shorebird	Pasture	50.1	31.5	79.1	29
	STGR	All	100.0	100.0	100.0	3
McVille	Shorebird	All	51.6	19.9	129.5	6
	Shorebird	DNC	51.6	19.9	129.5	6
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	4
Minnewaukan	Shorebird	All	84.7	60.6	117.8	14
	Shorebird	DNC	100.0	100.0	100.0	9
	Shorebird	Pasture	57.3	18.4	170.6	5
	STGR	All	43.6	18.8	99.0	12
Pleasant Lake	Shorebird	All	48.0	32.3	70.9	47
	Shorebird	DNC	38.4	9.6	143.8	5
	Shorebird	Pasture	49.3	32.7	74.0	42
	STGR	All	100.0	100.0	100.0	1
Rock Lake	Shorebird	All	4.2	0.0	1260.5	2
	Shorebird	DNC	4.2	0.0	1260.5	2
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	n/a	n/a	n/a	0
Whitman	Shorebird	All	0.0	0.0	0.0	1
	Shorebird	DNC	0.0	0.0	0.0	1
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	n/a	n/a	n/a	0
Mean	Shorebird	All	52.0	38.6	65.4	130
	Shorebird	DNC	54.6	30.3	79.0	53
	Shorebird	Pasture	50.8	39.8	61.7	77
	STGR	All	63.2	33.3	93.1	30

STGR = Sharp-tailed Grouse

Table 5. Mayfield nest success for 2005 on control blocks and areas outside trapped blocks, by species group and habitat type. Lower and upper CI indicate lower and upper 95% confidence interval limits, as in Klett et al. (1986). Mean Mayfield estimates and corresponding confidence limits were calculated after grouping by block.

Block	Group	Habitat	Mayfield Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Calio	Shorebird	All	82.1	55.2	121.4	13
	Shorebird	DNC	82.1	55.2	121.4	13
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	31.5	2.9	294.6	2
Church's Ferry	Shorebird	All	100.0	100.0	100.0	5
	Shorebird	DNC	100.0	100.0	100.0	5
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	31.0	7.8	116.8	7
Crary	Shorebird	All	100.0	100.0	100.0	3
	Shorebird	DNC	100.0	100.0	100.0	3
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	35.5	7.9	148.9	6
Leeds	Shorebird	All	50.7	19.1	130.3	8
	Shorebird	DNC	50.7	19.1	130.3	8
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	28.1	2.0	325.3	2
Mean Controls	Shorebird	All	78.4	44.2	112.6	29
	Shorebird	DNC	78.4	44.2	112.6	29
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	32.3	27.6	37.0	17
Outside Blocks	Shorebird	All	63.7	33.4	119.6	8
	Shorebird	DNC	63.7	33.4	119.6	8
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	39.3	21.6	70.6	28

STGR = Sharp-tailed Grouse

Table 6. Mayfield nest success for 2006 on control blocks and areas outside trapped blocks, by species group and habitat type. Lower and upper CI indicate lower and upper 95% confidence interval limits, as in Klett et al. (1986). Mean Mayfield estimates and corresponding confidence limits were calculated after grouping by block.

Block	Group	Habitat	Mayfield Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Calio	Shorebird	All	0.0	0.0	0.0	2
	Shorebird	DNC	0.0	0.0	0.0	2
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	2
Courtenay	Shorebird	All	100.0	100.0	100.0	3
	Shorebird	DNC	100.0	100.0	100.0	3
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	70.0	34.1	141.7	7
Crary	Shorebird	All	n/a	n/a	n/a	0
	Shorebird	DNC	n/a	n/a	n/a	0
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	2.6	0.0	138.4	5
Leeds	Shorebird	All	59.8	21.0	164.1	5
	Shorebird	DNC	59.8	21.0	164.1	5
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	6
Mean Controls	Shorebird	All	59.9	-45.5	165.3	10
	Shorebird	DNC	59.9	-45.5	165.3	10
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	65.2	-5.3	135.7	21
Outside Blocks	Shorebird	All	61.6	42.6	88.6	36
	Shorebird	DNC	53.8	33.5	85.6	29
	Shorebird	Pasture	100.0	100.0	100.0	7
	STGR	All	19.0	5.8	60.3	26

STGR = Sharp-tailed Grouse

Table 7. Logistic-exposure nest success for 2005 on trapped blocks, by species group and habitat type. Mean logistic-exposure estimates were calculated after grouping by block and weighting by exposure days.

Block	Group	Habitat	Logistic-Exposure Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Cando	Shorebird	All	82.0	45.4	95.2	18
	Shorebird	DNC	80.5	42.2	94.7	17
	Shorebird	Pasture	100.0	100.0	100.0	1
	STGR	All	63.9	4.5	93.9	5
Harlow	Shorebird	All	5.9	0.0	17.0	26
	Shorebird	DNC	100.0	100.0	100.0	2
	Shorebird	Pasture	2.5	0.3	10.2	24
	STGR	All	29.6	0.0	84.6	2
McVille	Shorebird	All	100.0	100.0	100.0	7
	Shorebird	DNC	100.0	100.0	100.0	7
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	42.6	0.3	88.9	2
Minnewaukan	Shorebird	All	67.7	39.2	85.0	26
	Shorebird	DNC	86.3	35.6	98.0	12
	Shorebird	Pasture	51.3	17.1	78.0	14
	STGR	All	73.4	29.3	92.6	10
Pleasant Lake	Shorebird	All	58.7	24.4	81.9	14
	Shorebird	DNC	74.3	12.7	95.9	6
	Shorebird	Pasture	48.4	10.8	79.3	8
	STGR	All	100.0	100.0	100.0	1
Rolla	Shorebird	All	n/a	n/a	n/a	0
	Shorebird	DNC	n/a	n/a	n/a	0
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	1
Whitman	Shorebird	All	34.9	0.1	64.8	11
	Shorebird	DNC	34.9	0.1	64.8	11
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	3
Mean	Shorebird	All	54.7	35.8	73.6	102
	Shorebird	DNC	75.2	56.2	94.1	55
	Shorebird	Pasture	26.9	-0.3	54.2	47
	STGR	All	70.7	47.8	93.7	24

STGR = Sharp-tailed Grouse

Table 8. Logistic exposure nest success for 2006 on trapped blocks, by species group and habitat type. Mean logistic-exposure estimates were calculated after grouping by block and weighting by exposure days.

Block	Group	Habitat	Logistic-Exposure Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Bowden	Shorebird	All	n/a	n/a	n/a	0
	Shorebird	DNC	n/a	n/a	n/a	0
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	2
Cando	Shorebird	All	50.4	29.0	68.5	30
	Shorebird	DNC	48.6	27.3	67.2	29
	Shorebird	Pasture	100.0	100.0	100.0	1
	STGR	All	55.0	9.5	86.2	8
Harlow	Shorebird	All	57.6	34.7	75.1	30
	Shorebird	DNC	100.0	100.0	100.0	1
	Shorebird	Pasture	56.4	33.3	74.3	29
	STGR	All	100.0	100.0	100.0	3
McVille	Shorebird	All	57.4	11.2	87.1	6
	Shorebird	DNC	57.4	11.2	87.1	6
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	4
Minnewaukan	Shorebird	All	88.0	40.8	98.2	14
	Shorebird	DNC	100.0	100.0	100.0	9
	Shorebird	Pasture	70.7	0.1	95.3	5
	STGR	All	54.1	19.6	79.5	12
Pleasant Lake	Shorebird	All	52.3	33.5	68.2	47
	Shorebird	DNC	44.2	0.0	81.8	5
	Shorebird	Pasture	53.4	33.2	70.1	42
	STGR	All	100.0	100.0	100.0	1
Rock Lake	Shorebird	All	47.5	0.0	90.4	2
	Shorebird	DNC	47.5	0.0	90.4	2
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	n/a	n/a	n/a	0
Whitman	Shorebird	All	0.0	0.0	0.0	1
	Shorebird	DNC	0.0	0.0	0.0	1
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	n/a	n/a	n/a	0
Mean	Shorebird	All	57.0	41.4	72.6	130
	Shorebird	DNC	57.9	38.6	77.2	53
	Shorebird	Pasture	56.3	35.0	77.5	77
	STGR	All	69.6	49.1	90.2	30

STGR = Sharp-tailed Grouse

Table 9. Logistic exposure nest success for 2005 on control blocks and areas outside trapped blocks, by species group and habitat type. Mean logistic-exposure estimates were calculated after grouping by block and weighting by exposure days.

Block	Group	Habitat	Logistic-Exposure Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Calio	Shorebird	All	86.5	36.0	98.0	13
	Shorebird	DNC	86.5	36.0	98.0	13
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	38.7	0.2	87.7	2
Church's Ferry	Shorebird	All	100.0	100.0	100.0	5
	Shorebird	DNC	100.0	100.0	100.0	5
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	37.2	4.8	72.9	7
Crary	Shorebird	All	100.0	100.0	100.0	3
	Shorebird	DNC	100.0	100.0	100.0	3
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	44.6	4.2	81.9	6
Leeds	Shorebird	All	56.7	0.1	86.9	8
	Shorebird	DNC	56.7	0.1	86.9	8
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	31.3	0.0	85.3	2
Mean Controls	Shorebird	All	83.5	50.1	117.0	29
	Shorebird	DNC	83.5	50.1	117.0	29
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	39.3	12.0	66.6	17
Outside Blocks	Shorebird	All	64.3	3.8	124.8	8
	Shorebird	DNC	64.3	3.8	124.8	8
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	46.4	30.0	62.9	28

STGR = Sharp-tailed Grouse

Table 10. Logistic exposure nest success for 2006 on control blocks and areas outside trapped blocks, by species group and habitat type. Mean logistic-exposure estimates were calculated after grouping by block and weighting by exposure days.

Block	Group	Habitat	Logistic-Exposure Nest Success (%)	Lower CI	Upper CI	N (number of nests)
Calio	Shorebird	All	0.0	0.0	0.0	2
	Shorebird	DNC	0.0	0.0	0.0	2
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	2
Courtenay	Shorebird	All	100.0	100.0	100.0	3
	Shorebird	DNC	100.0	100.0	100.0	3
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	73.4	2.1	92.5	7
Crary	Shorebird	All	n/a	n/a	n/a	0
	Shorebird	DNC	n/a	n/a	n/a	0
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	10.8	0.1	49.6	5
Leeds	Shorebird	All	68.7	0.1	94.9	5
	Shorebird	DNC	68.7	0.1	94.9	5
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100.0	100.0	100.0	6
Mean Controls	Shorebird	All	60.6	5.4	115.9	10
	Shorebird	DNC	60.6	5.4	115.9	10
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	68.4	43.2	93.6	21
Outside Blocks	Shorebird	All	74.5	46.0	103.1	36
	Shorebird	DNC	66.0	34.8	97.2	29
	Shorebird	Pasture	100.0	100.0	100.0	7
	STGR	All	64.5	47.4	81.6	26

STGR = Sharp-tailed Grouse

The difference in visual obstruction between shorebird nests and random locations in the field was highly significant in fields dominated by DNC, such as CRP and most WPAs, was highly significant. In these fields, Robel measurements were lower at shorebird nest sites (1.84 ± 0.07dm) than at random locations in the field (2.74 ± 0.12dm) (Fig.3; $F_{1,262} = 16.82$, Tukey-Kramer comparison, $P < 0.001$). This relationship was driven by the tendency of Wilson's Phalaropes to preferentially nest on more sparse sites than in the surrounding field of DNC (Fig.4; $P < 0.001$). The trend was not observed in pastures for shorebirds as a group, where Robel measurements at nest sites (1.59 ± 0.11dm) were similar to random locations in the field (1.38 ± 0.20dm) (Fig.3; $F_{1,262} = 16.82$, Tukey-Kramer comparison, $P = 0.818$). However, Common Snipe preferred more densely vegetated nest sites than found in the surrounding pasture (Fig.5; $P = 0.013$). Visual obstruction did not differ between nest sites in DNC and pastures for shorebirds as a group (Fig.6; $F_{1,292} = 16.82$, Tukey-Kramer comparison, $P = 0.206$), nor for any of the three most abundant shorebird species (Fig.7). There were no year effects in any of the previous vegetation analyses. Visual obstruction does appear to affect fine scale nest site selection, as vegetation density 1m from the nest and at nest sites did not differ (Fig.8; Tukey-Kramer comparison, $P = 0.968$).

There was a significant relationship between proportion of grass cover and nest site vs. random location (Fig.9; $F_{3,376} = 8.50$, $P < 0.001$). In 2005, there was more grass cover at random locations (50.5 ± 2.4%) than at nest sites (39.2 ± 2.4%) (Fig.10; Tukey-Kramer comparison, $P = 0.006$). Upland Sandpipers were largely responsible for this relationship, as they chose nest sites with less grass cover than was in the surrounding field (Fig.10; $P = 0.002$). However, in 2006 there was no difference between nest sites (48.8 ± 1.7%) and random locations for all shorebirds

(54.2 ± 1.7%) (Fig.9; Tukey-Kramer comparison, $P = 0.137$). Grass canopy cover did not differ between years at nests and in the surrounding field (Fig.9; $F_{1,376} = 2.03$, $P = 0.156$).

There was a significant year effect in forb coverage between nest and random locations (Fig.11; $F_{1,376} = 4.05$, $P = 0.045$). In 2005, shorebirds showed no differential use of forb cover at nest sites (32.9 ± 2.3%) compared to random locations in the field (27.2 ± 2.3%) (Tukey-Kramer comparison, $P = 0.326$). The direction of the trend was reversed in 2006, with forbaceous cover at random locations in the field (21.0 ± 1.7%) greater than at nest sites (18.4 ± 1.7%); however, the relationship was not significant (Tukey-Kramer comparison, $P = 0.698$). Wilson's Phalaropes preferentially nested in areas containing less forb coverage than random sites in 2006 (Fig.12; $P = 0.050$).

There was a significant year effect between native cover and nest site vs. random locations in the field (Fig.13; $F_{1,376} = 3.93$, $P = 0.048$). Native vegetation made up a greater proportion of vegetation at nest sites than at random locations in 2006 (Tukey-Kramer comparison, $P < 0.001$), but not in 2005 (Tukey-Kramer comparison, $P = 0.318$). For the three most common species, only Common Snipe and Wilson's Phalarope showed a preference for native vegetation at nest sites in 2006 (Fig.14; $P < 0.001$ for each)

Cover of invasive species was greater at random locations than at nest sites (Fig.15; $F_{1,376} = 32.24$, $P < 0.001$). There was not a significant year interaction with invasive species ($F_{1,376} = 2.41$, $P = 0.122$). Common Snipe and Wilson's Phalaropes each preferred nest sites with less invasive cover than random sites (Fig.16; $P = 0.015$ and < 0.001, respectively). Finally, litter depth was significantly thicker at random locations than at nest sites (Fig.17; $F_{1,369} = 16.32$, $P < 0.001$); however, out of the three most common species this relationship holds only for Wilson's Phalarope (Fig.18; $P = 0.003$).

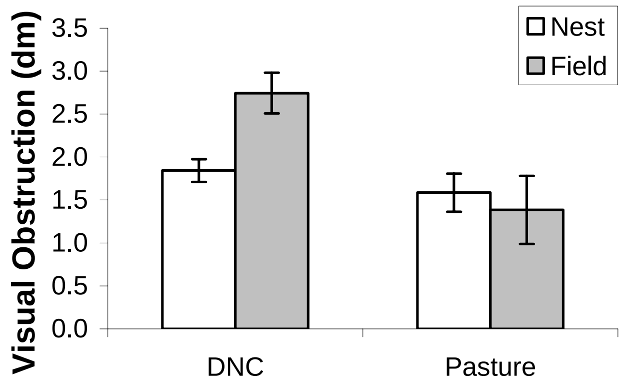


Figure 3. Visual obstruction of vegetation at shorebird nest sites and random locations in surrounding field by habitat (mean ± 95% C.I.). In dense nesting cover (DNC), Robel measurements were significantly greater at random locations than at nests (n = 158, P < 0.001). Robel measurements were not different within pasture habitats (n = 48, P = 0.818).

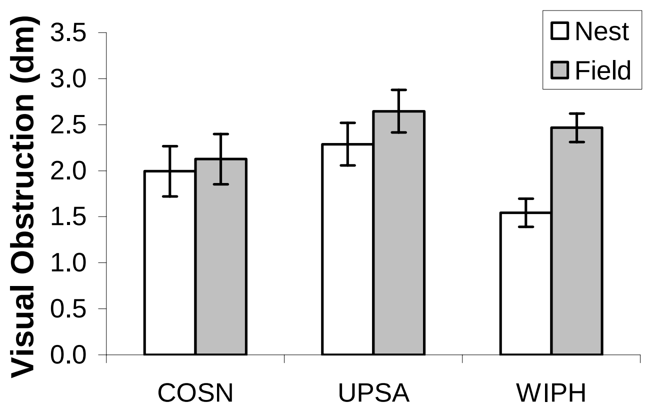


Figure 4. Visual obstruction of vegetation in DNC fields at nest sites and random locations of the three most abundant shorebird species: Common Snipe (COSN; n = 34), Upland Sandpiper (UPSA; n = 47), and Wilson's Phalarope (WIPH; n = 83) (mean ± 95% C.I.). Robel measurements were not significantly different for COSN or UPSA (*P* = 0.899 and 0.137 respectively), however for WIPH visual obstruction was significantly greater at random locations than at nests (*P* <0.001).

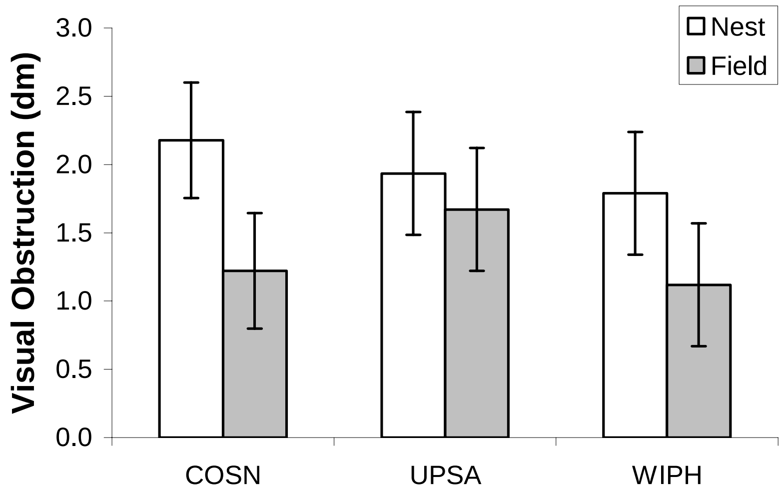


Figure 5. Visual obstruction of vegetation in pastures at nest sites and random locations of the three most abundant shorebird species: Common Snipe (COSN; n = 7), Upland Sandpiper (UPSA; n = 15), and Wilson's Phalarope (WIPH; n = 19) (mean ± 95% C.I.). Robel measurements were not significantly different for UPSA or WIPH (P = 0.844 and 0.164, respectively), however for COSN visual obstruction was significantly greater at nest sites than random locations (P = 0.013).

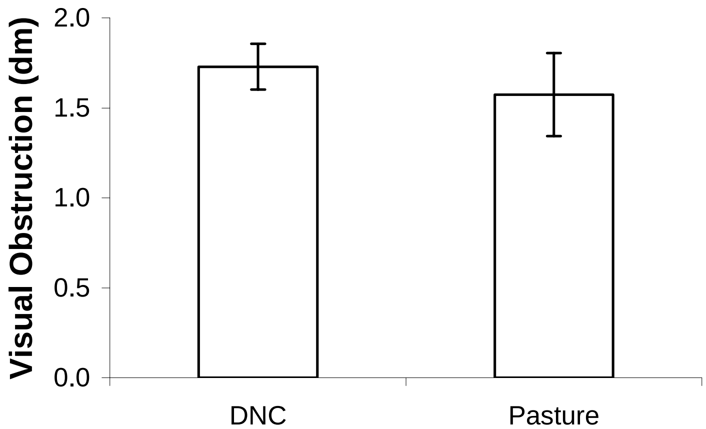


Figure 6. Visual obstruction of vegetation at shorebird nest sites in DNC fields and pastures (mean ± 95% C.I.). Robel measurements were not significantly different between habitat types (n_{DNC} = 158, $n_{pasture}$ = 48, P = 0.272).

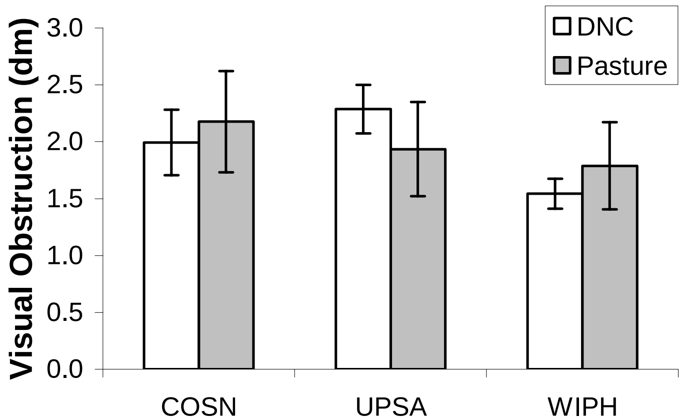


Figure 7. Visual obstruction of vegetation at nest sites in DNC fields and pastures of the three most abundant shorebird species: Common Snipe (COSN; $n_{DNC} = 17$, $n_{pasture} = 7$), Upland Sandpiper (UPSA; $n_{DNC} = 47$, $n_{pasture} = 15$), and Wilson's Phalarope (WIPH; $n_{DNC} = 83$, $n_{pasture} = 19$) (mean ± 95% C.I.). Robel measurements were not significantly different between habitat types for any species ($P_{COSN} = 0.478$, $P_{UPSA} = 0.135$, and $P_{WIPH} = 0.233$).

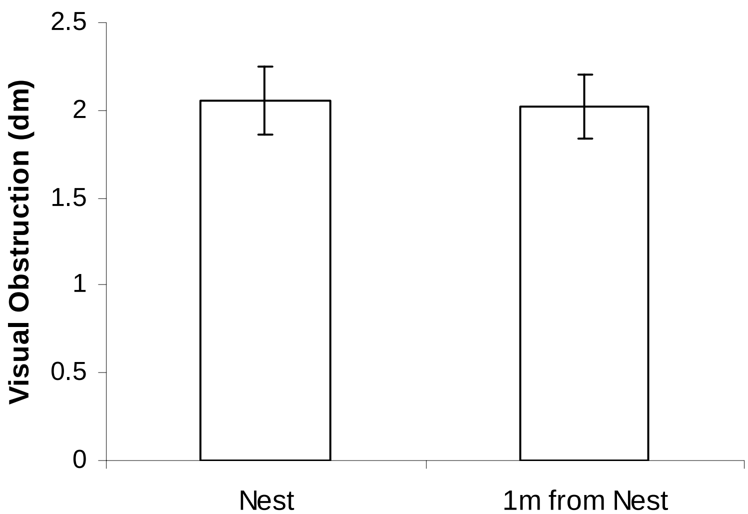


Figure 8. Visual obstruction of nest sites and points 1m from nest sites (mean ± 95% C.I.). Nest (n = 78) and 1m (n = 78) from nest were not different ($P = 0.968$).

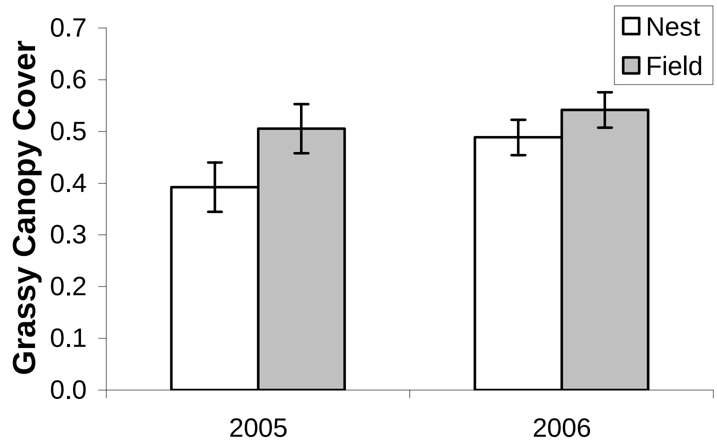


Figure 9. Grassy proportions of Daubenmire plots (mean ± 95% C.I.). Field plots had a significantly greater proportion of grass than nest plots in 2005 (n_{nest} = 65, P = 0.006), while nest and field plots did not significantly differ in 2006 (n_{nest} = 125, P = 0.137).

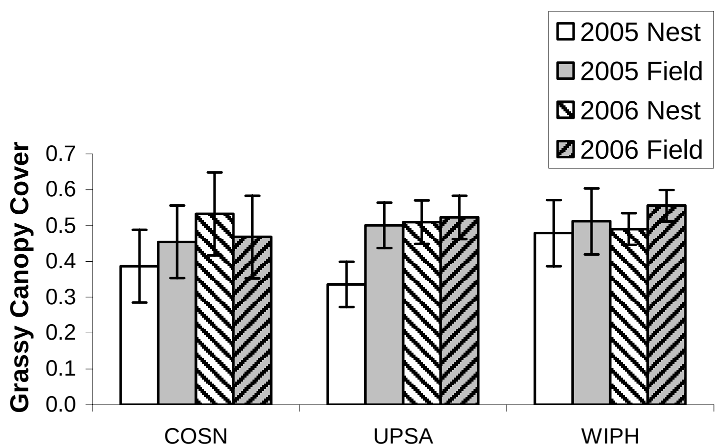


Figure 10. Grassy proportions of Daubenmire plots at nest sites and random locations of the three most abundant shorebird species: Common Snipe (COSN; n_{2005} = 13, n_{2006} = 10), Upland Sandpiper (UPSA; n_{2005} = 24, n_{2006} = 26), and Wilson's Phalarope (WIPH; n_{2005} = 19, n_{2006} = 82) (mean ± 95% C.I.). Within year and species, field plots had a significantly greater proportion of grass than nest plots in 2005 for UPSA (P = 0.002), while nest and field plots did not significantly differ for any other location pair within year.

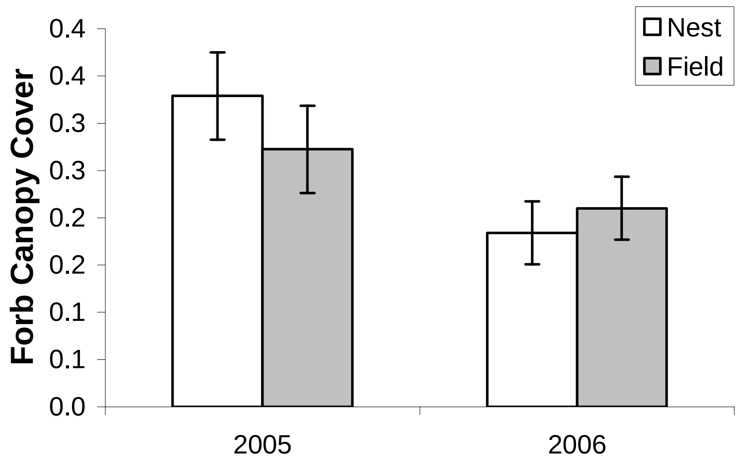


Figure 11. Forbaceous proportions of Daubenmire plots (mean ± 95% C.I.). Nest and field plots did not significantly differ in 2005 (n = 65, P = 0.326) or 2006 (n = 125, P = 0.698).

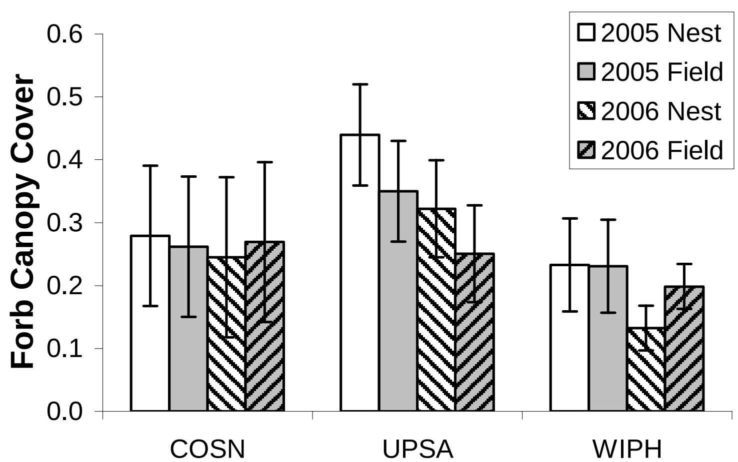


Figure 12. Forbaceous proportions of Daubenmire plots at nest sites and random locations of the three most abundant shorebird species: Common Snipe (COSN; n_{2005} = 13, n_{2006} = 10), Upland Sandpiper (UPSA; n_{2005} = 24, n_{2006} = 26), and Wilson's Phalarope (WIPH; n_{2005} = 19, n_{2006} = 82) (mean ± 95% C.I.). Within year and species, field plots had a significantly greater proportion of forb cover than nest plots in 2006 for WIPH (P = 0.050), while nest and field plots did not significantly differ for any other location pair within year.

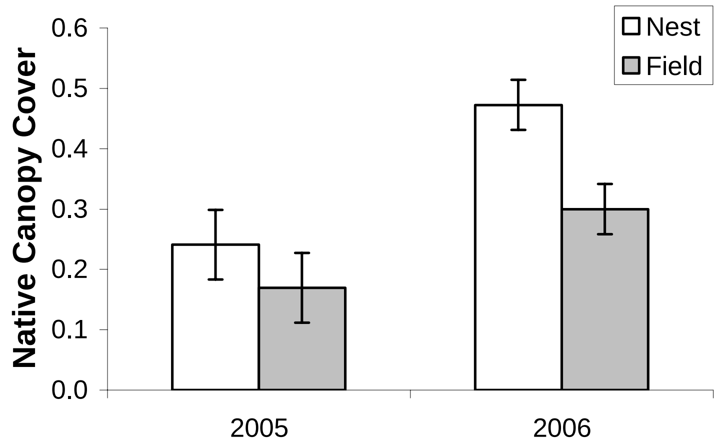


Figure 13. Proportions of native vegetation in Daubenmire plots (mean ± 95% C.I.). Nest plots did not differ from the surrounding field in 2005 (n = 65, *P* = 0.318), however plots centered on nests had a greater proportion of native cover than random plots in 2006 (n = 125, *P* < 0.001).

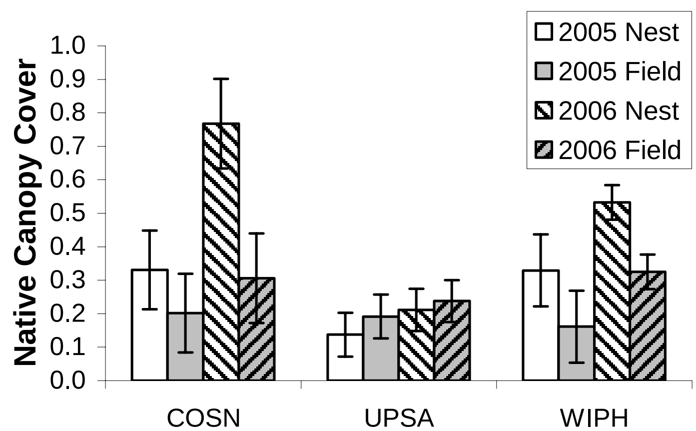


Figure 14. Proportions of native vegetation in Daubenmire plots at nest sites and random locations of the three most abundant shorebird species: Common Snipe (COSN; n_{2005} = 13, n_{2006} = 10), Upland Sandpiper (UPSA; n_{2005} = 24, n_{2006} = 26), and Wilson's Phalarope (WIPH; n_{2005} = 19, n_{2006} = 82) (mean ± 95% C.I.). Within year and species, nest plots had a significantly greater proportion of native cover than field plots in 2006 for COSN and WIPH (*P* < 0.001 for each), while nest and field plots did not significantly differ for any other location pair within year.

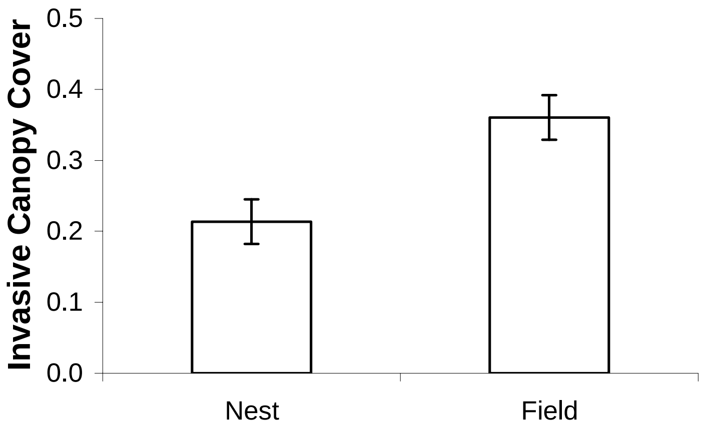


Figure 15. Proportions of invasive vegetation in Daubenmire plots (mean ± 95% C.I.). Random locations had a significantly greater proportion of invasive cover than nest plots (n = 190, *P* < 0.001).

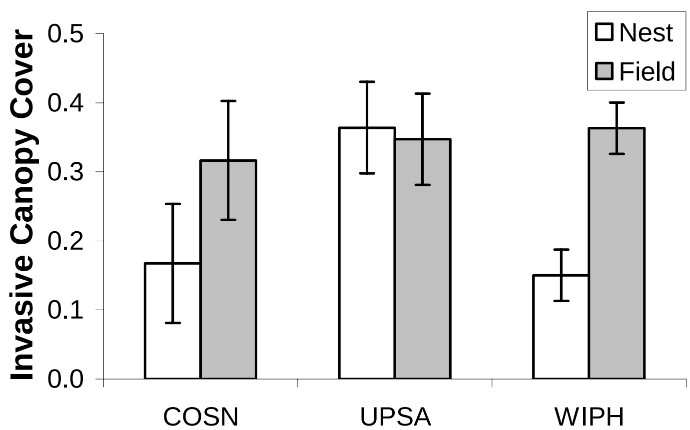


Figure 16. Proportions of invasive vegetation in Daubenmire plots at nest sites and random locations of the three most abundant shorebird species: Common Snipe (COSN; n = 23), Upland Sandpiper (UPSA; n = 50), and Wilson's Phalarope (WIPH; n = 101) (mean ± 95% C.I.). Field plots differed from nest plots for COSN and WIPH (*P* = 0.015 and < 0.001, respectively), but not for UPSA (*P* = 0.748).

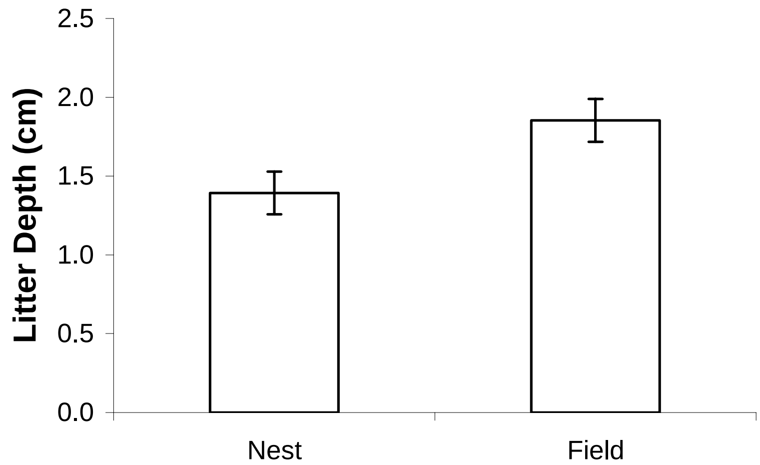


Figure 17. Depth of litter layer at nest vs. random locations in the field (mean ± 95% C.I.). Field plots had a significantly thicker litter layer (n = 186, $P < 0.001$).

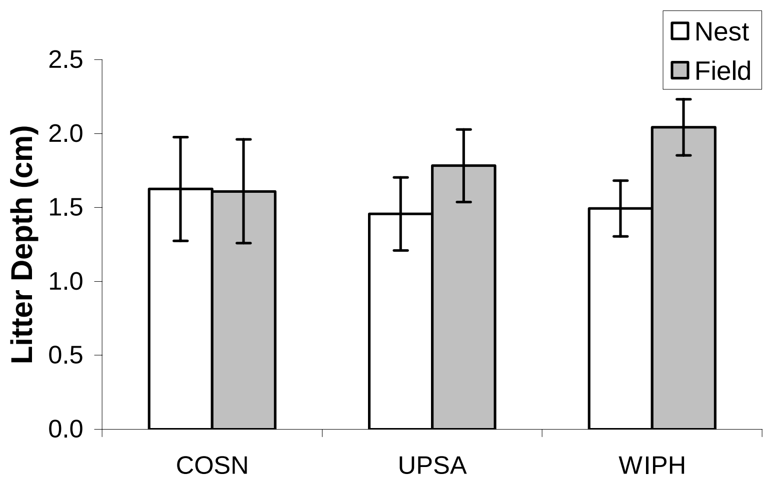


Figure 18. Depth of litter layer at nest sites and random locations of the three most abundant shorebird species: Common Snipe (COSN; n = 23), Upland Sandpiper (UPSA; n = 50), and Wilson's Phalarope (WIPH; n = 101) (mean ± 95% C.I.). Field plots had a significantly thicker litter layer for WIPH ($P = 0.0030$), while nest and field plots did not significantly differ for COSN or UPSA ($P = 0.977$ and 0.065, respectively).

DISCUSSION AND MANAGEMENT IMPLICATIONS

Nesting habitat appeared to have a stronger impact on shorebird nest success than did predator removal. Mayfield and logistic exposure nest success estimates were both over 1.5 times greater in DNC than in pastures, whereas nest success did not differ between trapped and control blocks. Nest success also did not differ between trapped and control blocks for Sharp-tailed Grouse, which were found almost entirely in DNC fields. The difference in nest success between habitats for shorebirds may have multiple explanations, including greater predation and flooding risk in pastures, and increased incidental destruction by livestock in pastures. Plots within control blocks were overwhelmingly dominated by DNC. The fact that shorebird nests were found almost exclusively in DNC on control blocks may bias pooled contrasts of control and trapped block nest success estimates, because trapped block nest success combined both DNC and pasture nests. In addition, nest success estimates were based on relatively small sample samples of nests. On 3 of 4 control blocks in both 2005 and 2006 I found less than 10 shorebird nests.

There was little difference between Johnson-adjusted Mayfield and logistic exposure nest success estimates. As published shorebird egg flotation schedules become more common (see Mabee et al. 2006), Mayfield estimates may become more reliable due to increased precision in aging eggs. However, at the present time I suggest using the logistic exposure model for studies of shorebird nest success, as this method does not rely on estimation of incubation stage.

In fields with relatively dense vegetation, shorebirds, especially Wilson's Phalaropes and Upland Sandpipers, appear to select nest sites with more sparse vegetation than is found in the surrounding field, consistent with the results of other studies (Higgins et al. 1979, Kantrud and Higgins 1992). Also, shorebirds tend to select nest sites where there has been sparse vegetation

in the past, as indicated by a thinner litter layer. In pastures, however, Common Snipe and Wilson's Phalarope each nested in vegetation that was more dense than found at random in the field. Regardless of the surrounding habitat, Wilson's Phalaropes tended to nest in vegetation approximately 15cm tall, whereas Common Snipe and Upland Sandpipers nested in vegetation approximately 22cm tall.

Shorebird preferences for grassy and forbaceous nest sites shifted between years, with Upland Sandpipers avoiding grassy sites in 2005 and Wilson's Phalarope avoiding more forb-dominated nest sites in 2006. In 2006, shorebirds exhibited a preference for nest sites in native vegetation, consistent with results obtained by Kantrud and Higgins (1992). Finally, shorebirds appear to avoid nest sites dominated by invasive plants, such as Leafy Spurge (*Euphorbia esula*), Canada Thistle (*Cirsium arvense*), Kentucky Bluegrass (*Poa pratensis*), Smooth Brome (*Bromus inermis*), Stinging Nettle (*Urtica dioica*), and Wormwood (*Artemisia absinthium*).

In my study, vegetation surrounding a typical shorebird nest may be described as relatively short, sparse, native grassland. Creation of such habitat has not been the primary goal of recent grassland restoration efforts in North Dakota (such as the creation of Waterfowl Production Areas and Conservation Reserve Program contracts), which have overwhelmingly been focused upon the establishment of dense nesting cover for waterfowl. This cover has traditionally been comprised of tall, dense plant species, such as Tall and Intermediate Wheatgrasses, Smooth Brome, and Alfalfa. While habitat restoration of Waterfowl Production Areas will continue to focus primarily on waterfowl habitat requirements, there is also room within this framework for shorebird management. Many fields that are being returned to wildlife habitat contain patches of soil unsuitable for the growth of typical DNC species. Given that the vegetation on such patches will not become adequately dense for most waterfowl, management

objectives could shift in these areas to shorter native grasses that provide excellent shorebird habitat. In addition to providing nest sites for shorebirds, I suspect that these patches would also be attractive to waterfowl, such as Northern Pintail (*Anas acuta*) and Blue-winged Teal (*A. discors*), which tend to nest in more sparse cover than Mallard (*A. platyrhynchos*) and Gadwall (*A. strepera*) (Klett et al. 1988, Greenwood et al. 1995).

My results also suggest that shorebirds avoid nesting in habitats dominated by invasive species. For this reason, I suggest that natural resource management groups continue their efforts towards the control and eradication of invasive species in North Dakota. In conjunction, while certain invasive species such as Kentucky Bluegrass and Smooth Brome may yield agricultural revenue, efforts could be made to limit the propagation of such species, and promote suitable native forage alternatives such as Blue Grama (*Bouteloua gracilis*), Green Needlegrass (*Nassella viridula*), Needle and Thread (*Stipa comata*), and Switchgrass (*Panicum virgatum*).

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VITA

Darren Kirk Wiens was born on December 5, 1981. The son of a farmer and teacher, Darren grew up on a farm where he learned to respect and enjoy the outdoors. While this appreciation never left him, much of Darren's extracurricular time was spent practicing and performing his other true loves, sports and music. Darren attended Kipling School in Kipling, Saskatchewan, and graduated in 2000. That year, he moved to Burnaby, British Columbia, to begin his undergraduate degree at Simon Fraser University. Darren's curiosity in the natural sciences prompted him to pursue a degree in biology, focusing on ecology and evolution. When not enrolled in classes, Darren was employed as a research technician, the first of which position was with the Delta Waterfowl Foundation. Darren graduated with his Bachelor of Science degree in 2005. Connections with Delta, particularly Dr. Frank Rohwer and Dr. Elizabeth Loos, led Darren to begin his master's degree at Louisiana State University.