NORTH DAKOTA GAME AND FISH DEPARTMENT

Final Report

Shorebird Nest Success and Nest-Site Selection in the Devils Lake Wetland Management District

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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). Included in this assemblage of grassland nesting 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 declines in much of the world's grassland nesting bird species is the conversion of grassland to cultivated cropland (Krebs et al. 1999). This transformation has resulted in a very 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 as the available grassland habitat shrinks (Davis 2005). As a crucial consideration of wildlife management plans, habitat requirements of certain species must be identified. In an effort to aid in the effectiveness and efficiency of grassland restoration and management, my project is concerned with determining nest-site selection criteria for shorebird species breeding in eastern North Dakota. Specifically, I will quantify 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.

As a second result of fragmentation, habitat edges increase as grassland patches decrease in size. Many edges are preferentially frequented by mammalian nest predators such as 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 productivity of some shorebird species may also 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 predator abundance and efficiency. In the 1960s and 1970s, numerous studies were performed using toxicants to reduce waterfowl nest predator abundances, and 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 this management practice became outdated, 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 2003). Songbirds have also received modest attention in predator removal research, although nest success rates appear to remain unchanged (Dion et al. 1999, Dion et al. 2000).

Interestingly, while songbird nest success was not affected in these studies, the primary cause of nest failure shifted from the usual case of intermediate mammalian predation to predation by small mammals, such as ground squirrels (Dion et al. 1999). 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). If such a situation exists in areas of intermediate predator reduction, then the 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 rates on par with waterfowl, due to increased small mammal predation pressure. I will investigate the effects of medium-sized mammalian predator removal on nest success rates in shorebirds and other species of ground nesting birds. Specifically, I will test to determine if predator removal increases nest success as is common for waterfowl species, decreases nest success as predicted in situations of trophic cascade, or remains unchanged.

Studies of nest success typically employ the Mayfield method and require an estimate of nest initiation date for each nest (Johnson 1979). Initiation date is generally calculated by backdating from the date of discovery 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 the use of 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. Even though 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

Study Timeline

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.

Study Site

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), while four blocks serve as controls and were not managed for predators. Within each treatment block, nest searching was on 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. Additionally, nest searching was conducted on plots located within three miles of the treatment blocks, Waterfowl Production Areas outside of blocks, as well as areas outside plots within the treatment blocks, 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 (*Vulpes vulpes*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*). The distribution of traps is determined by the trapper, although trap placement is restricted to land within the boundaries of the treatment block. Predator removal efficacy is assumed to be similar between trappers, as financial incentives are offered 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.

Eggs were floated in order 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 data, each 0.1 days incubated/incubation period is associated with an increase of 23.25º of an egg's long axis to horizontal ($r = 0.8597$). This relationship was used to help identify categories that would be useful for analysis, yet practical to estimate visually in the field. I classified incubation stage as outlined in Figure 1. Incubation days could be assigned to recorded incubation stages by backdating and using published incubation period data (Colwell and Oring 1988, Gratto-Trevor 2000, Higgins and Kirsch 1975, Howe 1982, Jackson and Jackson 2000, Mueller 1999, Robinson et al. 1997), from nests with a known hatch date and projecting from laying-stage nests (Fig. 2). Figure 2 was constructed from data of Wilson's Phalaropes and Upland Sandpipers, the most commonly found shorebirds which also have similar incubation periods, 23 days. Incubation days for other species were scaled in proportion to values in Figure 2.

Habitat measurements were also 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). Due to the fact that measurements at the nest and 1m from the nest were not significantly different in 2005 (see figure 4) 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 of 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 and litter depth throughout the season is assumed to be negligible.

Statistical Analyses

I used analysis of variance to compare vegetation density at nests, 1m from nests, and at random locations in the surrounding field. I used two-tailed t-tests to compare proportions of grasses, forbs, native, and invasive vegetation at shorebird nests and random locations in the field. I also used t-tests to compare nest success on trapped vs. control blocks (two-tailed), and dense nesting cover (DNC) vs. pasture (one-tailed).

All results are reported as mean ± 1 standard error, except nest success rates which are reported as Mayfield estimates and corresponding confidence intervals (Klett et al. 1986).

RESULTS

In total, we found 577 ground nesting bird nests (Tables 1 and 2; 273 nests in 2005, and 304 nests in 2006). Of these, 315 belonged to shorebirds (Tables 1 and 2; 139 nests in 2005, and 176 nests in 2006).

Shorebird nest success was not significantly different between control (73.6%) and trapped blocks (50.9%) when all habitats and years were combined (Tables 3 – 6; t = 1.45, df = 18, $P = 0.1655$). Likewise, there was no significant difference between the success of shorebird nests in dense nesting cover (DNC) habitats in control (73.6%) and trapped blocks (63.8%) (Tables 3 – 6; t = 0.74, df = 18, $P = 0.4684$). 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. Nest success was higher for shorebirds nesting in DNC (66.4%) than for shorebirds nesting in pasture (41.0%) (Tables 3 – 6; t = 2.78, df = 26, $P = 0.01$). Finally, sharp-tailed grouse nest success did not significantly differ between control (50.1%) and trapped blocks (61.5%) (Tables 3 – 6; t = -0.87, df = 19, $P = 0.3957$). Habitats were not separated for sharp-tailed grouse, as nests were found almost exclusively in fields dominated by DNC.

When habitats were treated separated, the difference in visual obstruction between nest and random locations in the field was significant only in fields dominated by DNC, such as CRP and on most WPAs (Fig. 3; $F_{7,262} = 16.82$, $P < 0.0001$). In these fields, Robel measurements were significantly lower at nest sites (1.84 ± 0.13dm) than at random locations in the field (2.74 ± 0.24dm) (Tukey-Kramer comparison, $P < 0.0001$). The trend was reversed in pastures, where Robel measurements at nest sites (1.59 ± 0.22dm) were greater than at random locations in the field (1.38 ± 0.40dm) although differences were not significant (Tukey-Kramer comparison, $P = 0.8177$). Visual obstruction does appear to affect microhabitat nest site selection, as locations 1m from the nest and nest sites did significantly differ (Fig. 4; Tukey-Kramer comparison, $P = 0.9679$).

There was a significant year interaction in the relationship between grass canopy cover at nests and in the surrounding field (Fig. 5; $F_{3,487} = 5.89$, $P = 0.0156$). In 2005, there was significantly more grass covering random locations in the field (49.0%) than at nest sites (39.2%) (Tukey-Kramer comparison, $P = 0.0195$). However, in 2006 there was no difference between nest sites (48.9%) and the surrounding field (50.2%) (Tukey-Kramer comparison, $P = 0.9748$).

There was also a significant year interaction between forb coverage between nest and random locations (Fig. 6; $F_{3,487} = 13.90$, $P = 0.0002$). In 2005, shorebirds showed no preference for forbaceous cover at nest sites (32.9%) compared to random locations in the field (28.6%) (Tukey-Kramer comparison, $P = 0.5341$). The relationship was significant in 2006, with forbaceous cover at random locations in the field (26.9%) greater than at nest sites (18.5%) (Tukey-Kramer comparison, $P = 0.0195$).

Native vegetation made up a higher proportion of vegetation at nest sites than at random locations within the field in both 2005 (Fig. 7; Tukey-Kramer comparison, $P = 0.0251$) and 2006 (Tukey-Kramer comparison, $P < 0.0001$).

Finally, cover of invasive species was significantly greater at random locations than at nest plots (Fig.8; $F_{3,487} = 20.03$, $P < 0.0001$). There was not a significant year interaction ($F_{3,487} = 1.39$, $P = 0.2382$).

Litter depth was significantly thicker at random locations than at nest sites (Fig. 9; $F_{3,479} = 14.12$, $P = 0.0002$).

DISCUSSION AND MANAGEMENT IMPLICATIONS

Nesting habitat appeared to have a stronger impact on shorebird nest success than did predator removal. Mayfield nest success was over 1.5 times greater in DNC than in pastures, while it was not different between trapped and control blocks. This difference may have multiple explanations, including higher predation and flooding risk in pastures, and increased incidental destruction by livestock in pastures. Plots within control blocks are overwhelmingly dominated by DNC. The fact that nests may only be found in DNC on control blocks may bias nest success between control and trapped blocks, and may explain the relatively high total shorebird nest success on controls compared with trapped blocks. In addition, Mayfield estimates were based on relatively small sample samples of nests: fewer than 10 nests on 3 of 4 control blocks in both 2005 and 2006. Thus, each successful nest has a greater impact on nest success on control blocks.

Shorebirds appear to select nest sites with more sparse vegetation than is found in the surrounding field, especially in fields of relatively dense vegetation, consistent with the results of other studies (Higgins et al. 1979, Kantrud and Higgins 1992). As well, shorebirds tend to select nest sites where there has been sparse vegetation in the past, as indicated by a thinner litter layer. However, it should be noted that interspecific differences in vegetation density preferences have been reported in other studies (Colwell and Oring 1990), but I was unable to investigate these differences due to the small sample size for many species in my study.

Shorebird preferences for grassy and forbaceous nest sites shifted between years, from avoiding grassy sites in 2005 to avoiding more forbaceous nest sites in 2006. Shorebirds appear to show 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, 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 replanted grassland plots contain patches of soil unsuitable for the growth of tall grasses. Given that the vegetation on such patches will not become adequately dense for most waterfowl, management objectives could shift in these areas to those for other species. My results suggest that optimal shorebird habitat should be comprised of high proportions of native grass and forbs. In addition to providing nest sites for shorebirds, I suspect that these patches would also be attractive to certain waterfowl species, such as Northern Pintail (*Anas acuta*) and Blue-winged Teal (*A. discors*) that tend to nest in more sparse cover than Mallard (*A. platyrhynchos*) and Gadwall (*A. strepera*).

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 forage alternatives.

Table 1. 2005 Nest summary of shorebirds and other ground nesting birds 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	Northen Harrier	Virgina Rail	Short-eared Owl	Sharp-tailed Grouse	Wild Turkey	**Other Ground Nest 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. 2006 Nest summary of shorebirds and other ground nesting birds in northeastern North Dakota.

	Shorebirds								Other Ground Nesting Birds						
	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	**Other Ground Nest Total**	**Block Total**
Trapped Blocks															
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. 2005 Mayfield nest success 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	100	100	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	100	100	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	100	100	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

Table 4. 2006 Mayfield nest success 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	100	100	2
Cando	Shorebird	All	49.0	31.7	75.0	30
	Shorebird	DNC	47.8	30.5	74.3	29
	Shorebird	Pasture	100	100	100	1
	STGR	All	46.6	15.5	134.9	8
Harlow	Shorebird	All	50.9	32.3	79.5	30
	Shorebird	DNC	100	100	100	1
	Shorebird	Pasture	50.1	31.5	79.1	29
	STGR	All	100	100	100	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	100	100	4
Minnewaukan	Shorebird	All	84.7	60.6	117.8	14
	Shorebird	DNC	100	100	100	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	100	100	1
Rock Lake	Shorebird	All	4.2	0	1260.5	2
	Shorebird	DNC	4.2	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	1
	Shorebird	DNC	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

Table 5. 2005 Nest success 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

Table 6. 2006 Nest success 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	2
	Shorebird	DNC	0	0	0	2
	Shorebird	Pasture	n/a	n/a	n/a	0
	STGR	All	100	100	100	2
Courtenay	Shorebird	All	100	100	100	3
	Shorebird	DNC	100	100	100	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	0.029	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	100	100	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	100	100	7
	STGR	All	19.0	5.8	60.3	26

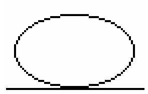
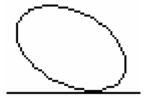
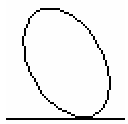
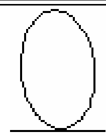
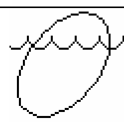
	Stage	Angle to Horizontal
	1	0º – 9º (on bottom)
	2	10º – 44º (on bottom)
	3	45º – 79º (on bottom)
	4	80º – 90º (on bottom)
	5	90º (at surface)
	6	60º – 90º (above surface)
	7	<60º (above surface)

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

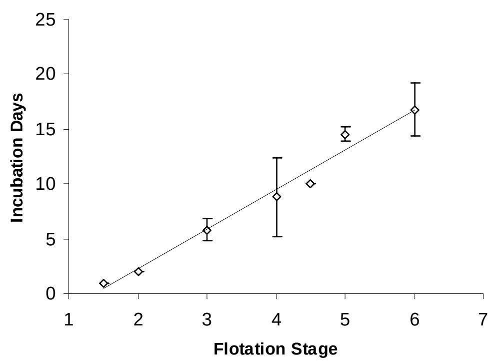


Figure 2. Relationship between flotation stage and incubation days (mean ± 95% C.I.). This relation is described by the equation $y = 3.6164x + 5.0115$, and $r^2 = 0.9784$.

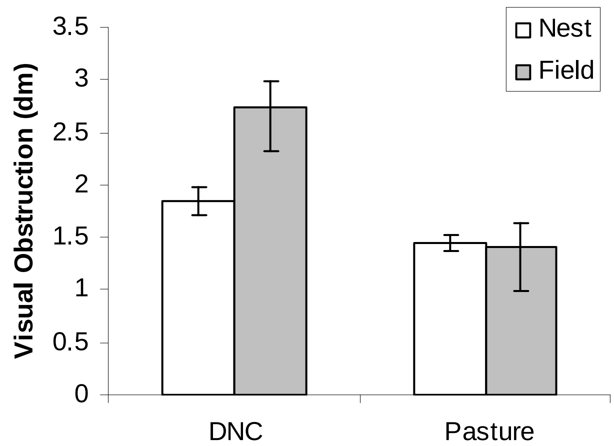


Figure 3. Visual obstruction of vegetation at shorebird nest sites and random locations in surrounding field by habitat (mean ± 95% C.I.). In dense nesting cover (DNC), robel measurements were significantly greater at random locations than at nests ($P < 0.0001$). Robel measurements were not significantly different within pasture habitats ($P > 0.8177$).

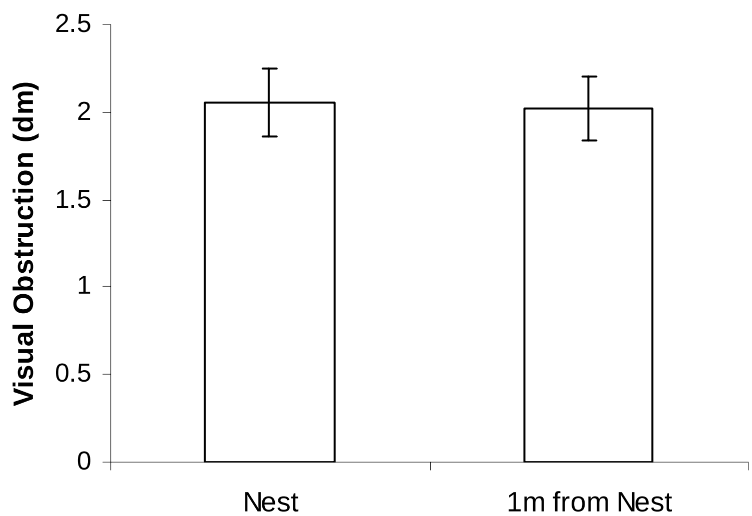


Figure 4. Visual obstruction of nest sites, points 1m from nest sites, and random locations in surrounding field (mean ± 95% C.I.). Nest and 1m from nest were not different ($P = 0.9679$).

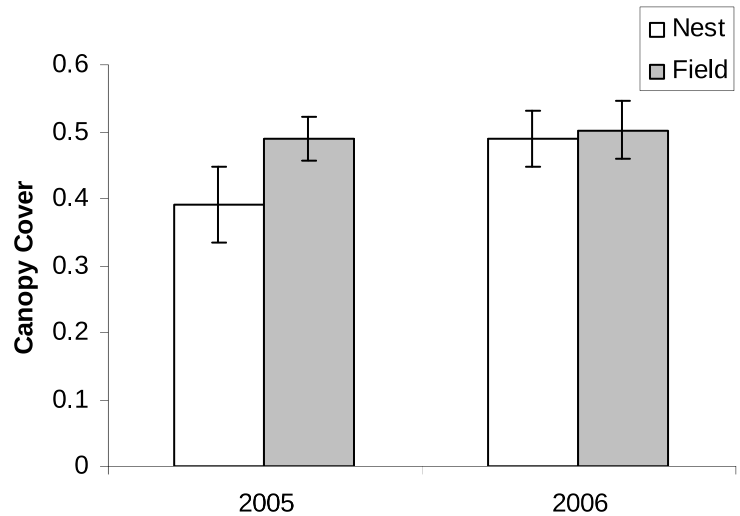


Figure 5. Grassy proportions of Daubenmire plots (mean ± 95% C.I.). Field plots had a significantly greater proportion of grass than nest plots in 2005 (*P* = 0.0195), while nest and field plots did not significantly differ in 2006 (0.9748).

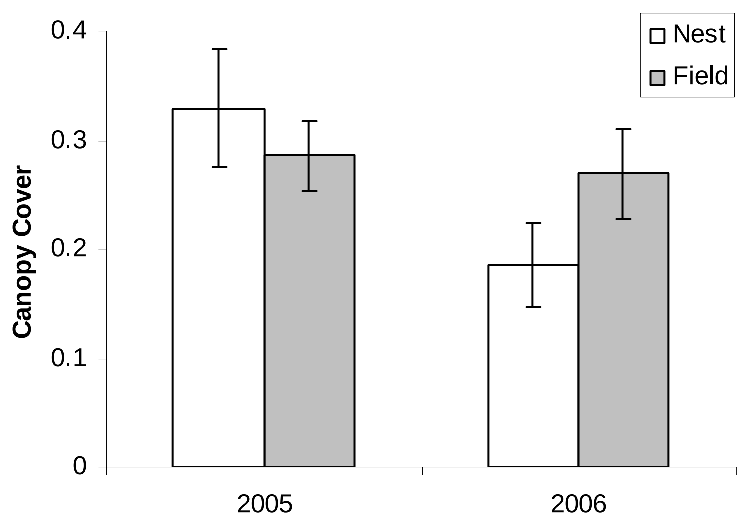


Figure 6. Forbaceous proportions of Daubenmire plots (mean ± 95% C.I.). Nest and field plots did not significantly differ in 2005 (*P* = 0.5341), while field plots had a significantly greater proportion of forbaceous cover than nest plots in 2006 (*P* = 0.0195).

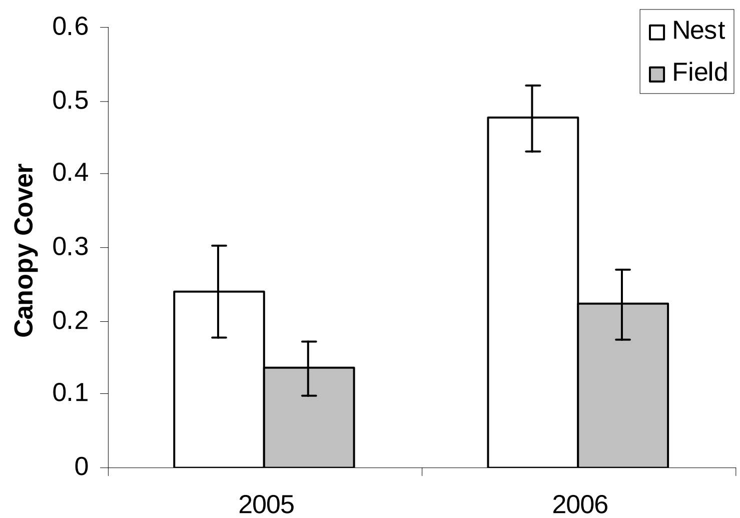


Figure 7. Proportions of native vegetation in Daubenmire plots (mean ± 95% C.I.). Nest plots had a significantly greater proportion of native cover than field plots in both 2005 ($P = 0.0251$) and 2006 ($P < 0.0001$).

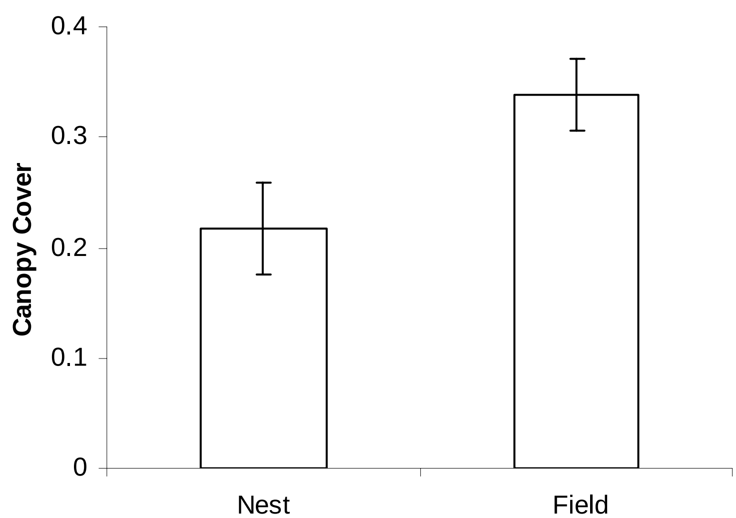


Figure 8. Proportions of invasive vegetation in Daubenmire plots (mean ± 95% C.I.). Random locations had a significantly greater proportion of invasive cover than nest plots ($P < 0.0001$).

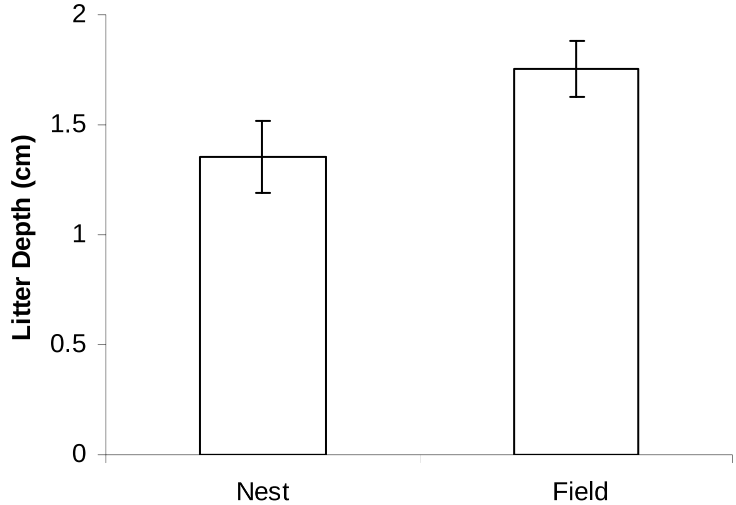


Figure 9. Depth of litter layer at nest vs. random locations in the field (mean ± 95% C.I.). Field plots had a significantly thicker litter layer (P = 0.0002).

LITERATURE CITED:

Balser, D. S., H. H. Dil, and H. K. Nelson. 1968. Effect of predator reduction on waterfowl nesting success. Journal of Wildlife Management 32:669-682.

Beauchamp, W. D., R. R. Koford, T. D. Nudds, R. G. Clark, and D. H. Johnson. 1996. Long-term declines in nest success of prairie ducks. Journal of Wildlife Management 60:247-257.

Bowen, B. S., and A. D. Kruse. 1993. Effects of grazing on nesting by Upland Sandpipers in northcentral North Dakota. Journal of Wildlife Management 57:291-301.

Chodachek, K. D. 2003. Evaluation of repeated removal of mammalian predators on waterfowl nest success and density. M.S. Thesis, Louisiana State University, Baton Rouge, Louisiana, USA.

Colwell, M.A., and L.W. Oring. 1988. Breeding biology of Wilson's Phalarope in southcentral Saskatchewan. Wilson's Bulletin 100:567-582.

Colwell, M.A., and L.W. Oring. 1990. Nest site characteristics of prairie shorebirds. Canadian Journal of Zoology 68:297-302.

Daubenmire, R. F. 1959. A canopy coverage method of vegetational analysis. Northwest Science 33:43-64.

Davis, S.D. 2005. Nest-site Selection Patterns and the Influence of Vegetation on Nest Survival of Mixed-grass Prairie Passerines. The Condor 107:605-16.

Dion, N., K. A. Hobson, and S. Lariviere. 1999. Effects of removing duck-nest predators on nesting success of grassland songbirds. Canadian Journal of Zoology 77:1801-1806.

Dion, N., K. A. Hobson, and S. Lariviere. 2000. Interactive effects of vegetation and predators on the success of natural and simulated nests of grassland songbirds. Condor 102:629-634.

Duebbert, H. F. and H. A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. Journal of Wildlife Management 38:257-265.

Duebbert, H. F. and J. T. Lokemoen. 1980. High duck nesting success in a predator-reduced environment. Journal of Wildlife Management 44:428-437.

Garrettson, P. R., F. C. Rohwer, J. M. Zimmer, B. J. Mense, and N. Dion. 1996. Effects of mammalian predator removal on waterfowl and non-game birds in North Dakota. Transactions of the North American Wildlife and Natural Resource Conference 61:94-101.

Garrettson, P. R., and F. C. Rohwer. 2001. Effects of mammalian predator removal on production of upland-nesting ducks in North Dakota. Journal of Wildlife Management 65:398-405.

Gratto-Trevor, C. L., F. Cooke, and R. I. G. Morrison. 1983. Nesting success of yearling and older breeders in the Semipalmated Sandpiper, *Calidris pusilla*. Canadian Journal of Zoology 61:1133-1137.

Gratto-Trever, C.L. 2000. Marbled Godwit. The Birds of North America 13:492.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildlife Monographs 128:1-57.

Hays, H., and M. LeCroy. 1971. Field criteria for determining incubation stage in eggs of the common tern. Wilson Bulletin 83:425-429.

Helmers, D. L., and C. L. Gratto-Trevor. 1996. Effects of predation on migratory shorebird recruitment. Transactions North American Wildlife and Natural Resources Conference 61:50-61.

Henke, S. E., and F. C. Bryant. 1999. Effects of coyote removal on the faunal community in western Texas. Journal of Wildlife Management 63:1066-1081.

Higgins, K.F., and L.M. Kirsch. 1975. Some aspects of the breeding biology of the Upland Sandpiper in North Dakota. Wilson Bulletin 87:96-102.

Higgins, K.F., L.M. Kirsch, M.R. Ryan, and R.B. Renken. 1979. Some ecological aspects of Marbled Godwits and Willets in North Dakota. Prairie Naturalist 11:115-118.

Hoff, M. J. 1999. Predator trapping on township-sized blocks: does duck nesting success increase? M.S. Thesis, Louisiana State University, Baton Rouge, Louisiana, USA.

Hooftman, D.A.P., R.C. Billeter, B. Schmid, and M. Diemer. 2004. Genetic Effects of Habitat Fragmentation on Common Species of Swiss Fen Meadows. Conservation Biology 18:1043-1051.

Houston, C. S. 1999. Decline in Upland Sandpipers populations: history and interpretations. Blue Jay 57:136-142.

Houston, C.S., and D.E. Bowen, Jr. 2001. Upland Sandpiper. The Birds of North America 15:580.

Howe, M.A. 1982. Social organization in a nesting population of Eastern Willets. Auk 99:88-102.

Howe, M. A., P. H. Geissler, and B. A. Harrington. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biological Conservation 49:185-199.

Jackson, B.J.S., and J.A. Jackson. 2000. Killdeer. The Birds of North America 13:517.

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. The Auk 96:651-661.

Johnson, R. G., and M. D. Schwartz. 1993. The Conservation Reserve Program and grassland birds. Conservation Biology 7:934-937.

Kantrud, H.A., and K.F. Higgins. 1992. Nest and nest site characteristics of some ground-nesting, non-passerine birds of northern grasslands. Prairie Naturalist 24:67-84.

Kirsch, L. M., and K. F. Higgins. 1976. Upland Sandpiper nesting and management in North Dakota. Wildlife Society Bulletin 4:16-20.

Klett, A.T., H.F. Duebbert, C.A. Faanes, and K.F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. U.S. Fish and Wildlife Service, Resource Publication 158. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. (Version 16JUL97).

Knopf, F. 1992. Faunal mixing, faunal integrity, and the biopolitical template for diversity conservation. Transactions North American Wildlife and Natural Resources Conference 57:330-342.

Krebs, J.R., J.D. Wilson, R.B. Bradbury, and G.M. Siriwardena. 1999. The Second Silent Spring? Nature 400:611-612.

Lynch, G. M. 1972. Effect of strychnine control on nest predators of dabbling ducks. Journal of Wildlife Management 36:436-440.

Morrison, R. I. G., Y. Aubry, R. W. Butler, G. W. Beyersbergen, G. M. Donaldson, C. L. Gratto-Trevor, P. W. Hicklin, V. H. Johnston, and R. K. Ross. 2001. Decline of North American shorebird populations. Wader Study Group Bulletin 94:34-38.

Mueller, H. 1999. Common Snipe. The birds of North America. 11:417.

Paton, P.W.C. 1994. The effect of edge on avian nest success: How strong is the evidence? Conservation Biology 8:17-26.

Robel R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Robinson, J.A., L.W. Oring, J.P. Skorupa, and R. Boettcher. American Avocet. The Birds of North America 7:275.

Samson, F., and F. Knopf. 1994. Prairie conservation in North America. Bioscience 44:418-421.

Weller, M.W. 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management. 20:111-113.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management. 14:56-67.