NORTH DAKOTA GAME AND FISH DEPARTMENT

Final Report

Influence of Habitat Types on Waterfowl Nest Density and Success

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Influence of Habitat Types on Prairie Nesting Waterfowl Nest Density and Nest Success in Northeastern North Dakota, 2010 – 2013

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Abstract: Waterfowl representing 8 species of prairie nesting ducks were systematically surveyed from late-April thru late August, 2010 - 2013 to compare nest density, nest success and vegetative structure used by nesting ducks at either native restoration sites (Native) or non-native planted vegetation commonly known as dense nesting cover (DNC). We located 4,286 waterfowl nests over 4 breeding seasons. Nest densities in Native uplands averaged 1.13 (± .48) nests per acre compared with 1.41 (± .12) in DNC. These results indicated that sampled nest densities were not equal (.25 < P < .50) within these 2 cover types. Nest densities for 5 species of prairie nesting puddle ducks showed that they did not nest evenly across both habitat types examined (.10 <P < .25). Average Mayfield nest success equaled 38% (± 18%) for Native habitat compared to 48% (± 10%) for DNC; Mayfield results in either cover type over the 4 year study period was well above the minimal nest success of 15% needed to maintain prairie nesting waterfowl across northeast North Dakota. However, late season nest success in 2011 was lower than 15% in Native uplands suggesting that perhaps predators, nest cover, prior year's management, field location or all combined factors may contribute to explain the poor performance during that particular year. Nest success results for 2010, 2012 and 2013 indicated a more normalized and consistent nest success result within Native vegetation; nest success remained very consistent in DNC sites throughout the 4 years of investigations. Finally, habitat structure at waterfowl nest sites differed, vegetation height and visual obstruction were lower (.10 >p > .05) in Native habitat versus DNC, litter depth was not significantly different in either field type. Performance within either Native or DNC cover indicated that both restoration techniques used to restore upland habitats works well for prairie nesting ducks, but DNC has higher productivity both from a nest density and nest success perspective, especially for mallard and gadwall. However, plant species richness typified by Native restoration sites may provide a more resilient habitat type especially in the face of more frequent climatic oscillations, and may provide more niches and more habitat structural diversity for a greater diversity of wildlife species. Published data suggests that non-native grassland restorations lack resilience in the face of severe drought, and may be prone to accelerated invasion by noxious weeds and other non-native invasive species. Also, Native upland restoration techniques may play a more pivotal role towards diversifying prairie landscapes as DNC is a much shorter lived habitat type. Native habitat restoration methods have proven to be adequate for producing adequate nest cover for prairie nesting ducks. A more diversified and resilient landscape is argued by climate scientists as one critical activity needed to retard impending climate change, this study provides a baseline effort showing that localized waterfowl production objectives can be achieved with Native vegetation while potentially addressing a larger ecological question.

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completion, and interest in this waterfowl/habitat question. Also, Cami Dixon and Roger Hollevoet for soliciting funds and project support, Dustin VanThuyne, Brandon Hanson, J. Clint Perkins, Kyle Johnson and Sara Pederson of the U.S. Fish and Wildlife Service for numerous hours of field work, and Tom Buhl of the U.S. Geological Survey-Northern Prairie Wildlife Research Center for analyzing nest data.

Introduction

The Prairie Pothole Region (PPR), located in the north-central United States and Canada, serves as the primary breeding grounds for the majority (50-80%) of North America's waterfowl species (Bellrose 1980, Batt et al. 1989). Historically dominated by mixed and tall-grass prairies (Johnson et al. 2008) and named for its extensive range of uplands with wetlands interspersed within the landscape, the PPR provides excellent loafing, roosting, and nesting sites for the reproduction of waterfowl (Kantrud and Stewart 1977). The region has become a large area of concern in recent years as 47% of palustrine wetlands have been lost in North Dakota, 35% in South Dakota, and >95-99%% in Minnesota Iowa (Dahl 1990). Also alarming is the fact that ≥ 70% of the native grasslands in the region have been converted to other uses, with 60% being converted to agriculture (USDA 2000). Each year, more native prairie is disked up and converted into agriculture. The PPR is the most intensively managed landscape in North America despite its low population (Johnson et al. 1994).

Restoration of a fragmented landscape is difficult and time consuming considering the planning, monitory demands, actual restoration implementation, post-restoration management and habitat monitoring that is required to succeed in this venture. These activities in most cases take years to achieve. Broader yet is the adaptive management that co-occurs with these restoration activities, often times it is sagacious to conduct a restoration effort, evaluate the outcomes, them make adjustments to continuously improve the techniques. After all habitat features seem completed, monitoring the habitat to answer specific wildlife productivity questions should be the next phase of project development, as in the case of this study. Restoring native vegetation to the upland prairie landscape is not a new concept, but putting this technique into practice and evaluating its direct effectiveness for the benefit of prairie nesting waterfowl is new. Past restoration activities focused on non-native cool season grasses and forbs which were cheap, easy to establish, and provided a superior nesting cover for prairie ducks. Given the fact that during the 1950's – 1980's, the lack of nesting cover was alarming and planting upland grasses and forbs was seen as a major benefit for ducks and other wildlife species relying on some resemblance of prairie habitat structure. Over time however, problems began to exist with restoration efforts reliant upon non-native vegetation, and efforts were made to improve restoration techniques using native vegetation. A list of advantages (and disadvantages) to that end appeared, and since 1994 within the Devils Lake WMD, a mix of both dense nesting cover(DNC) and multi-species native vegetation (Native) restoration efforts have been practiced; both techniques have achieved abundant success and failures. What was not known is the effectiveness of Native multi-species upland mixes and how they perform for prairie nesting ducks.

Today, many stands of both DNC and Natives exist and biologist sought to monitor the effectiveness of both cover types with one simple question; is Native vegetation better, worse or about equal to DNC with respect to waterfowl productivity. Four basic objectives for this study were created;

A. Evaluate and compare nest density and nest success of waterfowl in fields of DNC and Native restoration habitat types where nest density is better than 1 nest per 5 acres of habitat, and nest success is greater than 15%.
B. Assess landscape variables that may impact waterfowl use of restored sites to assist DLWMD staff in prioritizing sites for restoration, and to provide habitat managers with structural "objectives" beneficial to nesting ducks.

C. Assess the vegetative components of each study field by collecting vegetative structure data at both waterfowl nests and at random locations for the purpose of detecting patterns of waterfowl nest site selection if they exist.
D. Monitor all species of nesting waterfowl separately and track the nesting phenology of each species throughout the nesting season to determine if early, middle or late nesting ducks have advantages or disadvantages related to nest success, and changes in vegetative structure throughout the breeding season.

Funding Activities
Funding for this study was made possible by multiple partners. Collectively, this project totaled $71,040.00 in SWG and non-federal matching dollars. All non-federal matching funds were provided by Southern Illinois University (SIU) and equaled $35,520.00. State Wildlife Grant awards totaling $14,850.00 was awarded to SIU, and fully spent. The remaining $20,607.00 SWG dollars were issued to the USFWS – Devils Lake Wetland Management District and fully spent by November, 2013.

Study Areas
We investigated numerous Waterfowl Production Areas (WPA) and 1 National Wildlife Refuge (Lake Alice NWR) for nesting ducks located within the Devils Lake Wetland Management District in northeastern North Dakota which encompassed 10,146 mi^2 (Figure 1). We monitored nesting ducks in 14 fields and the total area searched was approximately 1,235 acres in size (Figure 2) with the average size of field searched averaging 88 acres ($\pm$ 40ac.). Native upland habitat comprised 5 fields equaling 446 acres searched and 9 DNC fields totaling 779 acres. During the 2012 – 2013 filed seasons, the numbers of acres searched was reduced due to a reduction of observers (from 6 personnel to 2), roughly 350 acres of both Native and DNC was searched during those years. All sites selected we squarely located within the mixed-grass prairie portion within the District, and had numerous wetland densities associated within and adjacent to each site. Palustrine temporary, seasonal and semi-permanent wetland densities were very similar at each study site regardless of cover type. Throughout the 4 years of investigation, precipitation levels exhibited average to above average conditions while wetland conditions as measured by percent full were in very good (>75% - 100%) to excellent (>100%) condition.

Management of each field (past and present) was perhaps the most "uncontrollable" variable within the study, and this factor could not be quantified nor should not be overlooked. The reader is warned that some results may be affected by active management, but generally enough habitat had undergone a period of idleness (3 – 5 years from management) which allowed us to use waterfowl nest results in a meaningful way, and make predictions and model the effectiveness of Native and DNC nest cover and nest success.

Native Vegetation Defined
Experimentation with native seeding that took place 20 years ago in the Drift Prairie and Red River Valley areas of North Dakota usually included a limited mixture of 3-5 native warm-season grasses. Fields restored using Native vegetation within the past 10 years consisted primarily of over 20 species of cool and warm season grasses and forbs, arriving at roughly 50-75% grasses, and 50-25% forbs and small shrubs. We searched for nesting ducks within 5 fields restored with multi-species native mixtures; Native study field sizes averaged 89.2 acres ($\pm$ 37 ac) with the average age of the stand near 8 years. Please see Figure 3 for a typical sample of plants used and a planning sheet used in the actual Native upland restoration.

Dense Nesting Cover Defined

Traditionally, areas within the DLWMD and other WMD's throughout the PPR were re-seeded to herbaceous mixtures that typically included 4 plant species such as cool-season introduced grasses and legumes (intermediate wheatgrass [Agropyron intermedium], tall wheatgrass [Agropyron elongatum], and alfalfa [Medicago sativa] and/or sweetclover [Melilotus officinalis]). These mixtures, referred to as dense nesting cover were utilized from the early 1980's and continue today in a more limited capacity, typically on sites that contain higher than average salinity. The DNC seed mixture has been touted by many waterfowl biologists as a premium waterfowl nesting cover due to its robustness (i.e. high vegetation height and visual obstruction scores). We searched for nesting ducks within 9 fields restored with DNC and the average DNC field size investigated was 87 acres (± 47 ac) with the average stand age of 9 years.

Methods

Nest Density and Nest Success

We located upland nesting ducks using a modified cable chain dragged behind 2 all-terrain vehicles (Higgins et al. 1977) beginning in the last week of April until all new nest detections ceased, typically by the beginning of August. Each field was searched every 10 days to locate all new nest attempts and to obtain a measurement of nest density and also to detect nesting phenology of prairie ducks. Nests were simply tallied up and we took the number of nests found and divided by the total acreage which produced an output estimate of nests per acre. We marked each nest with a wooden stake 10 m north of the nest and placed a small orange metal rod directly next to the nest to assist in later detection of nest location. Data collected at the nest were recorded on USGS Habitat/Nest Record Cards; species of hen, number of eggs, incubation, and GPS coordinates, date detected etc. (Appendix 1). We determined the age of the nest by using a simple field candler as described by Weller (1956). Nests were revisited every 7-8 days until the fate of the nest was determined, and data recorded during those visits included date of visit, number of eggs present, incubation stage, and ultimately nest fate. Nests were considered successful if ≥1 eggs hatched. If nests failed, a USGS Nest Depredation Form (Appendix 2) was completed for analysis of not only the nest failure, but potentially the cause of nest depredation. Nest success was determined via two methods; 1)data collected in 2010 and 2011 was estimated for each habitat type (objectives 1 and 2) using Dinsmore's model in program MARK to estimate nest success and Mayfield nest density estimates to estimate nest density (Johnson and Shaffer 1990, Dinsmore et al. 2002, McPherson et al, 2003), 2) for Mayfield nest success estimates between 2012 and 2013, nest data cards were analyzed U.S Geological Survey - Northern Prairie Wildlife Research Center in Jamestown, North Dakota.

Field Vegetation, Species Composition and Physiognomy

Throughout the study, vegetation data was collected at each nest discovered as well as randomly within each field. Vegetation data was collected during two distinct phases of growth, during the early nesting season (May 1 – June 10) and again from June 11 – July 15. The purpose was determine the value or structural characteristics of early season residual cover and compare to later season new growth. One random point was created for every 5 acre in a field. At each random point and each nest site, we collected visual obstruction data using the method of Robel et al. (1970) to determine nest structure or visual obstruction used by nesting hens and recorded in decimeters. Random sites were likewise measured to detect whether nest sites used by ducks differed from random locations. Vegetation height was assessed visually with the same Robel pole and was averaged from simple visual estimations where at least 3 or more of the tallest stems could be used to determine a maximum vegetation height and likewise recorded in decimeters. Lastly, litter depth was measured randomly in each field and at each nest using a ruler and measured in centimeters. We used the belt transect method as describe by Grant et al. (2004) to obtain species composition or groups of species for each field studied.

Results

Nest Densities

Waterfowl nest densities were similar in both Native and DNC fields, but a slight advantage between the two cover types would hedge towards DNC. Table 1 represents four years of waterfowl nest density data collected at study sites across northeastern North Dakota.

Table 1. Nest densities of prairie nesting ducks within two habitat types, diverse native habitat restoration sites versus non-native dense nesting cover during the 2010 – 2013 breeding seasons within the Devils Lake Wetland Management District.

Field Type (nests)	Acres Searched	Nests/Acre	Field Type (nests)	Acres Searched	Nests/Acre
2010 Native (n=798)	445	1.793	2010 DNC (n=1,191)	790	1.508
2011 Native (n=515)	445	1.157	2011 DNC (n=1,020)	790	1.291
2012 Native (n=75)	88	0.852	2012 DNC (n=302)	237	1.274
2013 Native (n=114)	159	0.717	2013 DNC (n=271)	173	1.566
TOTALS	**1137**	**1.130 ($\pm$.479)**	**TOTALS**	**1990**	**1.410 ($\pm$.129)**

Species specific nest densities varied across sites, nesting puddle ducks including mallard, northern pintail, blue-winged teal, northern shoveler and gadwall were of primary focus. Other puddle duck nests that were detected included American wigeon and green-winged teal, but their numbers were too small for any meaningful analysis. We did detect several lesser scaup nests during the study and will create a separate table representing lesser scaup densities and nest success for that species. Table 2 represents nest densities of 5 commonly detected puddle duck species and their distribution within each studied habitat type.

Table 2. Nest densities of 5 species prairie nesting puddle ducks occurring within two habitat types, diverse native habitat restoration sites versus non-native dense nesting cover sites during the 2010 – 2013 breeding seasons within the Devils Lake Wetland Management District, North Dakota.

Species	Multi-species Native Cover Nests/Acre ($\pm$)	Dense Nesting Cover Nests/ Acre
Mallard	**.197 ($\pm$.06) (n=237)**	**.323 ($\pm$ .14) (n=506)**
Northern pintail	**.130 ($\pm$ .02) (n=140)**	**.134 ($\pm$.06) (n=239)**
Blue-winged teal	**.282 ($\pm$ .14) (n=410)**	**.277 ($\pm$ .10) (n=665)**
Northern shoveler	**.168 ($\pm$ .09) (n=232)**	**.177 ($\pm$ .07) (n=404)**
Gadwall	**.302 ($\pm$ .16) (n=421)**	**.432 ($\pm$ .10) (n=836)**

Nest densities for 5 species of prairie nesting puddle ducks showed that they did not nest evenly across both habitat types examined ($.10 < P < .25$). A simple arithmetic model (Species = Nest/Acre NATIVE x

100, Nest/Acre DNC x 100) examining 320 and 640 acres of prime nesting habitat of either type would predict numbers of nests a manager could expect given optimal breeding conditions (Table 3.).

Table 3. A simple arithmetic model simulating the expected gains in duck nests by restoring incrementally larger blocks of either multi-species native cover or dense nesting cover in landscapes with optimal precipitation and wetland densities within the Devils Lake Wetland Management District, North Dakota.

Species	Nest/Acre NATIVE	x 100 acre	x 320 acre	x 640 acre
Mallard	0.197	19.7	63.04	126.08
Northern pintail	0.130	13	41.6	83.2
Blue-winged teal	0.282	28.2	90.24	180.48
Northern shoveler	0.168	16.8	53.76	107.52
Gadwall	0.302	30.2	96.64	193.28
Species	Nest/Acre DNC	x 100 acre	x 320 acre	x 640 acre
Mallard	0.323	32.3	103.36	206.72
Northern pintail	0.134	13.4	42.88	85.76
Blue-winged teal	0.277	27.7	88.64	177.28
Northern shoveler	0.177	17.7	56.64	113.28
Gadwall	0.432	43.2	138.24	276.48

Overall, waterfowl nests initiated by nesting ducks are presented by species and by habitat type for the reviewer's information in Table 4.

Table 4. Nests by habitat type, year, and waterfowl species detected during 4 years of investigations at select locations within the Devils Lake Wetland Management District, North Dakota.

Nests by Species									
Year	Mallard	Pintail	Blue-winged teal	Northern shoveler	Gadwall	Green-winged teal	American wigeon	Lesser Scaup	Yearly Total
2010 Native	98	61	212	138	254	7	7	21	798
2010 DNC	126	96	315	234	346	5	4	65	1191
2011 Native	102	43	162	66	125	5	4	8	515
2011 DNC	191	85	274	115	317	0	2	36	1020
2012 Native	21	12	12	7	18	0	0	5	75
2012 DNC	128	18	48	32	71	0	0	5	302
2013 Native	16	24	24	21	24	0	0	3	112
2013 DNC	61	40	28	23	102	0	4	15	273
Totals	743	379	1075	636	1257	17	21	158	4286

Lesser Scaup
Lesser scaup, an upland nesting diving duck and the 6th most abundant species encountered during the study was regularly detected throughout all 4 nesting seasons and a total of 158 nests were detected. Scaup are a waterfowl species which exhibits very strong site fidelity, and of particular interest due to the fact that recent population indices have shown scaup populations in decline and therefore this species is of some elevated importance. Table 5 portraits both scaup nest densities within targeted habitats, and also includes nest success for scaup where analysis was conducted. Numbers of nests are fairly low so results may have high standard deviations from the nest success results, and it is not advisable to assume one habitat type is better than another for scaup.

Table 5. Lesser scaup nest densities and nest success at study locations of both native and non-native vegetation occurring 2010 – 2013 within the Devils Lake Wetland Management District, North Dakota.

Lesser Scaup Nests and Nest Success				
Survey year	Multi-species Native Habitat - Nests (Nest Density/Acre)	Native Habitat Nest Success	Dense Nesting Cover - Nests (Nest Density/Acre)	Dense Nesting Cover Nest Success
2010	21 (.04)	Unknown	65 (.08)	Unknown
2011	8 (.01)	Unknown	36 (.05)	Unknown
2012	5 (.05)	100%	5 (.02)	74%
2013	4 (.02)	21.70%	15 (.08)	21.40%

Nest Success
Nest success was rigorously monitored at all study sites over the four years of the study. Some 4,286 duck nests were deemed usable, and Mayfield estimates were generated for each nest from 2010 thru the 2013 nesting season. Likewise, comparisons were made at each study location to detect any patterns or advantages to ducks selecting either Native or DNC vegetation for nesting. Table 6 shows the overall nest success of nesting ducks within Native and DNC fields from 2010 – 2013 breeding seasons.

Table 6. Nest success by species and habitat type for all usable nests located from 2010 – 2013 waterfowl breeding season within the Devils Lake Wetland Management District, North Dakota.

Study Year	**Nests in Restored Native Cover**	**Mayfield Results in Native Cover**	**Nests in Dense Nesting Cover**	**Mayfield Results in Dense Nesting Cover**	**Seasonal Nest Summary**
2010	**798**	**48.00%**	**1191**	**42.00%**	**1989**
2011	**515**	**13.00%**	**1020**	**37.00%**	**1535**
2012	**75**	**56.00%**	**302**	**55.00%**	**377**
2013	**114**	**35.00%**	**271**	**58.00%**	**385**
Totals	**1,502**	**μ = 38% $\pm$ 18.7**	**2,784**	**μ = 48% $\pm$ 10.1**	**4,286**

Nest success results were well above long term average at all study areas during the study. Typically results for nest success have been historically below 20% in northeastern North Dakota from the 1970's - 2000, so this simple fact is really quite a unique phenomenon within this region of the state. Nest success results were similar for other waterfowl studies within the District between 2010 -2013 as well as conducted by Delta Waterfowl Foundation (Mike Buxton pers. comm).

Results from the 2011 field season however were most intriguing due to the low nest success discovered within Native stands during that season. Nest success results for that year were only 13%. Late season success during 2011 within Native stands was dismal (R. Haffele pers. comm.). However, all other field seasons failed to show this pattern, and 2010, 2012, and 2013 nest success remained consistent from the first, second and third period of the nesting season in both Native and DNC habitat types.

Nest Success Phenology

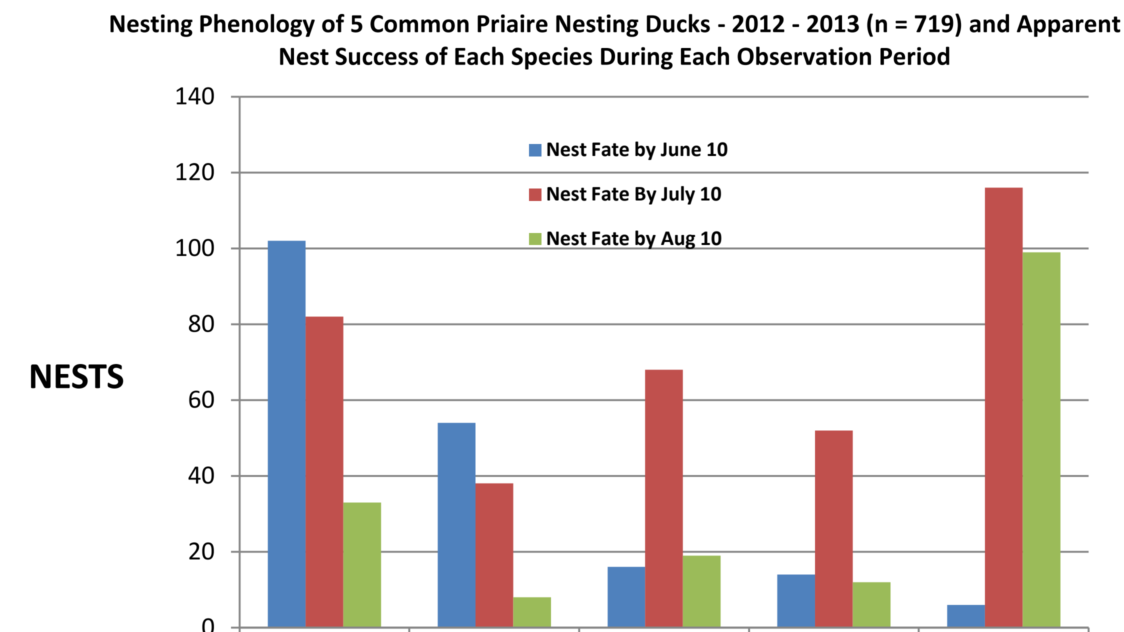
Of particular interest was nest success phenology; was waterfowl nest success equivalent during three periods of the breeding season? We looked at this question for the 2013 field season only, primarily due to the low late season nest success in Native habitat discover during the 2011 field season. We performed a quick assessment of nest success coupled with nest fates dates which were analyzed with apparent nest success as the metric. Time constraints prohibited using the standard Mayfield method to calculate nest success during these time phases; however we could compare the three measurable time periods against the overall Mayfield nest success conducted for each study field. We rated the first period of the season from April 25 thru 20 June, the second time phase from 21 June through 10 July, and the final phase from 11 July through 10 August. Table 7 shows the overall nest success of each study field during three specific time phases for the 2013 field season only.

Table 7. Waterfowl nest success phenology and apparent nest success during three distinct time phases during the 2013 breeding season. Also, a comparison of overall nest success at all study fields, and a comparison with the mean Mayfield nest success estimates during the 2013 field season.

Waterfowl Nest Phenology - Apparent Nest Success - 2013 (n=successful nests/total nests)						
Study Field	**Acreage Investigated**	**April 25 - June 10**	**June 11 - July 10**	**July 11 - August 20**	**Combined Season Apparent Success**	**Mayfield Nest Success Estimate, Combined Season (upper and lower hatch rates)**
Lake Alice NWR (DNC)	45	63% (n=15/24)	83% (n=77/93)	63% (n=46/73)	72% (n=138/190)	60% (52% - 70%)
Field 128 (DNC)	128	43% (N=10/23)	81% (N=39/48)	50% (N=10/20)	65% (n=59/90)	57% (46% - 72%)
Field 38 (Native)	38	0% (n=0/4)	50% (n=1/2)	75% (n=3/4)	40% (n=4/10)	15% (3% - 61%)
Field 101 (Native)	101	59% (n=20/34)	73% (n=27/37)	62% (n=13/21)	65% (n=60/92)	43% (33% - 58%)
Lake Alice NWR (Native)	20	0% (n=0/1)	67% (n=2/3)	88% (n= 7/8)	75% (n=9/12)	47% (24% - 91%)

Nest success of individual species and at which time they began or peaked during the nesting periods was also recorded. Figure 4 provides a wrap up of all species recorded during the 2013 field season and the periods with which their nesting efforts began, peaked and ended. This figure is useful for managers that choose to manage habitats, and avoid conflicts with nesting ducks which could still be actively incubating eggs after the August 1 date which is used as a standard date to begin habitat manipulations on Federal lands.

Figure 4. Nesting phenology of 5 common waterfowl species and their nest fate periods detected during the 2012 and 2013 field seasons within the Devils Lake Wetland Management District, North Dakota.



	Mallard	Northern Pintail	Blue Winged Teal	Northern Shoveler	Gadwall
Nest Fate by June 10	102	54	16	14	6
Nest Fate By July 10	82	38	68	52	116
Nest Fate by Aug 10	33	8	19	12	99

Habitat Evaluations

Random habitat evaluations and measurements of actual nest structure were repeatedly collected over 4 years of the study. Vegetation height was collected in 2010 and 2011, and was not collected in 2012 and 2013 due to time constrains. Both random and nest site visual obstruction data, and litter depth was collected during all 4 years of the study. Haffele's 2010 and 2011 data was wisely modeled using Akaike's Information Criterion (AIC) where many distinct habitat parameters were analyzed to determine which set of parameters offered habitat characteristics managers should strive to create if ideal waterfowl nesting habitat were their objectives. These AIC models also attempt to explain which habitat characteristics may explain variation in nest success. Table 8 includes the results of the AIC model run with data from 2010 and 2011 nests used for the results.

Table 8. Model selection results, including number of parameters (K) and model weight(w_i), used to examine factors affecting variations of nest success in multi-species native plantings and dense nesting cover in 2010-2011 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	ΔAICc	w_i	K	Deviance
Type*Year, Obs[a], Obs[2b], Ht[c], Ht[2d], Litter[e], Den[f]	6,702.51	0.80	0.71	10	6,682.51
Type*Year, Age[g], Obs, Obs^2, Ht, Ht^2, Litter, Den	6,704.46	1.94	0.27	11	6,682.45
Type*Year, Age, Ht, Ht^2, Litter, Den	6,711.47	8.96	0.01	9	6,693.47
Type*Year, Age, Obs, Ht, Ht^2, Litter, Den	6,713.36	10.85	0.01	10	6,693.36
Type*Year, Obs, Ht, Ht^2, Litter, Area[h], Den,	6,714.15	11.64	0.00	11	6,692.14
Type*Year, Age, Obs, Ht, Litter, Area, Den	6,714.45	11.94	0.00	10	6,694.45
Type*Year, Age, Obs, Ht, Ht^2, Den	6,715.05	12.53	0.00	9	6,697.04
Type*Year, Age, Obs, Ht, Ht^2, Litter, Den, Den[2i]	6,715.06	12.55	0.00	11	6,693.06
Type*Year, Age, Obs, Ht, Ht^2, Lit, Lit^2, Den, Den^2	6,716.40	13.89	0.00	12	6,692.40
Type*Year, Age, Obs, Litter, Area, Den	6,724.52	22.01	0.00	9	6,706.52
Type*Year, Age, Obs, Ht, Ht^2, Litter, Area	6,738.99	36.48	0.00	10	6,718.98
Type*Year	6,770.60	68.09	0.00	4	6,762.60
Type + Year	6,823.90	121.38	0.00	3	6,817.90
Year	6,855.96	153.45	0.00	2	6,851.96
Type	6,902.30	199.79	0.00	2	6,898.30
Null	6,917.01	214.49	0.00	1	6,915.01

[a]Cover density around nest
[b]Quadratic term for cover density around nest
[c]Height of vegetation around nest
[d]Quadratic term for height of vegetation
[e]Depth of litter at nest site
[f]Density of nest in the field
[g]Age of nest when found
[h]Area of undisturbed grassland connected to field
[i]Quadratic term for density of nests in field

AIC results indicate that cover density at the nest (visual obstruction), vegetation height, the quadratic term for vegetation height, litter depth, and size of grassland patch and density of nests in the field explained the most variation in nest success. Therefore, managers should strive to have objectives geared toward the improvement of these parameters to maximize productivity at waterfowl breeding sites.

Individual species nest success was also modeled in a similar fashion. Tables 9, 10, 11, 12 and 13 were taken from Haffele's M.S. Thesis as explanations of nest success variation within either Native or DNC vegetation for 5 species of upland nesting waterfowl.

Table 9. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of northern pintails in 2010-2011 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	ΔAICc	w_i	K	Deviance
Obs[a], Ht[c], Ht^2[d]	451.42	0.00	0.40	4	443.41
Age[g], Obs, Ht, Ht^2	452.22	0.79	0.27	5	442.19
Age, Obs, Obs^2[b], Ht, Ht^2	454.14	2.72	0.10	6	442.11
Age, Ht, Ht^2	454.73	3.31	0.08	4	446.72
Age, Obs, Obs^2, Ht,	455.17	3.74	0.06	5	445.15
Age, Obs, Obs^2, Ht, Ht^2, Litter[e]	455.94	4.51	0.04	7	441.90
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area[h]	457.85	6.42	0.02	8	441.80
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den[f]	458.15	6.72	0.01	9	440.08
Null	458.29	6.86	0.01	1	456.29
Age, Obs, Obs^2	458.66	7.23	0.01	4	450.64
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den, Den^2[i]	460.12	8.70	0.01	10	440.05

[a]Cover density around nest
[b]Quadratic term for cover density around nest
[c]Height of vegetation around nest
[d]Quadratic term for height of vegetation
[e]Depth of litter at nest site
[f]Density of nest in the field
[g]Age of nest when found
[h]Area of undisturbed grassland connected to field
[i]Quadratic term for density of nests in field

Table 10. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of northern shoveler in 2010-2011 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	ΔAICc	w_i	K	Deviance
Litter[e], Den[f]	1,046.58	0.00	0.57	3	1,040.57
Age[g], Litter, Den	1,048.55	1.97	0.21	4	1,040.54
Age, Obs[a], Litter, Den	1,050.43	3.85	0.08	5	1,040.42
Age, Obs, Obs[2b], Litter, Den	1,051.64	5.07	0.05	6	1,039.63
Age, Obs, Obs^2, Ht[c], Litter, Den	1,052.05	5.48	0.04	7	1,038.04
Age, Obs, Obs^2, Ht, Ht[2d], Litter, Den	1,053.03	6.46	0.02	8	1,037.02
Age, Obs, Obs^2, Ht, Ht^2, Den	1,054.14	7.6	0.01	7	1,040.12
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area[h], Den	1,054.98	8.40	0.01	9	1,036.96
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area[h], Den, Den[2i]	1,055.85	9.28	0.01	10	1,035.83
Null	1,064.55	17.98	0.00	1	1,062.55
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area	1,066.81	20.23	0.00	8	1,050.79

[a]Cover density around nest
[b]Quadratic term for cover density around nest
[c]Height of vegetation around nest
[d]Quadratic term for height of vegetation
[e]Depth of litter at nest site
[f]Density of nest in the field
[g]Age of nest when found
[h]Area of undisturbed grassland connected to field
[i]Quadratic term for density of nests in field

Table 11. Model selection results, including number of parameters (K) and model weight(w_i), used to examine factors affecting nest success of blue-winged teal in 2010-2011 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	ΔAICc	w_i	K	Deviance
Obs[a], Litter[e], Area[h], Den[f], Den[2i]	1,989.41	0.00	0.50	6	1,977.40
Age, Obs, Litter, Area, Den, Den^2	1,991.41	2.00	0.18	7	1,977.40
Age, Litter, Area, Den, Den^2	1,991.47	2.07	0.18	6	1,979.47
Age, Obs, Obs[2a], Litter, Area, Den, Den^2	1,992.81	3.40	0.09	8	1,976.80
Age, Obs, Obs^2, Ht[c], Litter, Area, Den, Den^2	1,994.72	5.31	0.04	9	1,976.70
Age, Obs, Obs^2, Ht, Ht[2d], Litter, Area, Den, Den^2	1,996.71	7.30	0.13	10	1,976.69
Age, Obs, Obs^2, Ht, Ht^2, Litter, Den, Den^2	2,001.79	12.39	0.00	9	1,983.78
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den	2,004.82	15.41	0.00	9	1,986.80
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area,	2,007.38	17.98	0.00	8	1,991.37
Age, Obs, Obs^2, Ht, Ht^2, Area, Den, Den^2	2,007.55	18.15	0.00	9	1,989.54
Null	2,015.79	26.39	0.00	1	2,013.79

[a]Cover density around nest
[b]Quadratic term for cover density around nest
[c]Height of vegetation around nest
[d]Quadratic term for height of vegetation
[e]Depth of litter at nest site
[f]Density of nest in the field
[g]Age of nest when found
[h]Area of undisturbed grassland connected to field
[i]Quadratic term for density of nests in field

Table 12. Model selection results, including number of parameters (K) and model weight(w_i), used to examine factors affecting nest success of gadwall in 2010-2011 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	ΔAICc	w_i	K	Deviance
Ht[c], Ht^{2}[d] Den[f], Den^{2}[i]	1,897.61	0.00	0.38	5	1,887.60
Age[g], Ht, Ht^2, Den, Den^2	1,898.4	0.83	0.25	6	1,886.43
Age, Obs[a], Ht, Ht^2 Den, Den^2	1,899.46	1.85	0.15	7	1,885.45
Age, Obs, Obs^{2}[b], Ht, Ht^2 Den, Den^2	1,900.88	3.27	0.07	8	1,884.87
Age, Obs, Obs^2, Ht, Den, Den^2	1,901.30	3.69	0.06	7	1,887.29
Age, Obs, Obs^2, Ht, Litter[e], Den, Den^2	1,901.71	4.10	0.05	9	1,883.69
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area[h], Den, Den^2	1,902.91	5.30	0.00	10	1,882.89
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area	1,904.60	6.99	0.00	7	1,890.59
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den	1,907.94	10.34	0.00	9	1,889.93
Null	1,913.28	15.67	0.00	1	1,911.28
Age, Obs, Obs^2, Den, Den^2	3,278.94	,381.34	0.00	5	3,268.94

[a]Cover density around nest
[b]Quadratic term for cover density around nest
[c]Height of vegetation around nest
[d]Quadratic term for height of vegetation
[e]Depth of litter at nest site
[f]Density of nest in the field
[g]Age of nest when found
[h]Area of undisturbed grassland connected to field
[i]Quadratic term for density of nests in field

Table 13. Model selection results, including number of parameters (K) and model weight(wi), used to examine factors affecting nest success of mallard in 2010-2011 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	ΔAICc	w_i	K	Deviance
Ht[c], Ht[2d] Den[f], Den[2i]	1,120.89	0.00	0.42	5	1,110.88
Age[g], Ht, Ht^2, Den, Den^2	1,121.46	0.56	0.31	6	1,109.44
Age, Obs[a], Ht, Ht^2 Den, Den^2	1,123.06	2.17	0.14	7	1,109.04
Age, Obs, Obs[2b], Ht, Ht^2 Den, Den^2	1,124.99	4.10	0.05	8	1,108.97
Age, Obs, Obs^2, Den, Den^2	1,126.86	5.97	0.02	6	1,114.85
Age, Obs, Obs^2, Ht, Ht^2, Litter[e], Den, Den^2	1,126.90	6.01	0.00	9	1,108.87
Age, Obs, Obs^2, Ht, Den, Den^2	1,127.15	6.26	0.00	7	1,113.13
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area[h], Den, Den^2	1,128.80	7.91	0.00	10	1,108.77
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den	1,129.77	8.87	0.00	9	1,111.74
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area	1,131.45	10.55	0.00	8	1,115.42
Null	1,140.26	19.37	0.00	1	1,138.26

[a]Cover density around nest
[b]Quadratic term for cover density around nest
[c]Height of vegetation around nest
[d]Quadratic term for height of vegetation
[e]Depth of litter at nest site
[f]Density of nest in the field
[g]Age of nest when found
[h]Area of undisturbed grassland connected to field
[i]Quadratic term for density of nests in field

During the 2012 and 2013 field seasons, nest sites were monitored along with random locations to discern patterns of habitat use by nesting ducks. This is very important data and will be beneficial to managers who need objective driven management strategies when burning, grazing or haying grasslands. Table 14 illustrates differences in Native stands and compares directly with DNC. As Haffle also concurred in his M.S. thesis, waterfowl selected habitat characteristics slightly less robust than habitat at random locations. In any event, these are “real world” objectives land managers can use to achieve ideal waterfowl habitat structure, or at least work towards that objective with upland habitat management prescriptions.

Table 14. Visual obstruction and litter depth data collected from waterfowl nests and from random locations at each study site during the 2012 – 2013 field seasons within the Devils Lake Wetland Management District, North Dakota.

2012-2013 Habitat Measurements	Random	Nests	Random	Nests	Random	Nests	Random	Nests	Random	Nests
	North (dm)		East (dm)		South (dm)		West (dm)		Litter (cm)	
Fld 38 (Native)	3.06	3.05	3.25	2.80	3.00	2.60	3.17	2.40	1.66	3.94
Fld 101 (Native)	3.73	2.68	3.28	2.47	3.40	2.30	3.43	2.34	5.24	4.21
LANWR (Native)	2.85	2.59	2.35	2.64	2.81	2.36	2.77	2.91	4.51	4.68
Native Averages	**3.21**	**2.77**	**2.96**	**2.64**	**3.07**	**2.42**	**3.12**	**2.55**	**3.80**	**4.28**
LANWR (DNC)	4.42	4.48	4.12	4.48	3.96	4.46	4.27	4.53	5.03	4.91
Fld 128 (DNC)	3.44	2.72	3.05	2.79	3.05	2.75	3.31	2.76	3.17	3.61
2012 DNC	3.82	3.46	4.04	3.24	3.86	3.03	3.96	3.35	4.59	3.66
DNC Averages	**3.89**	**3.55**	**3.74**	**3.50**	**3.62**	**3.41**	**3.85**	**3.55**	**4.26**	**4.06**

It is interesting to note that differences in visual obstruction between Native and DNC stands is consistently lower for Natives at all 4 cardinal locations compared with DNC. This suggests less robustness within Native stands, but also explains greater habitat heterogeneity in Native stands, which may be a habitat characteristic potentially supporting a greater diversity of wildlife. In any event, northern pintails, northern shoveler and blue-winged teal were found about equally in all cover types, while mallard and gadwall were found in greater abundance in DNC which concurred completely with Tables 9 – 13.

Discussion

I have decided to forego a litany of scientific citations for this part of the report. I would suggest for an excellent discussion regarding waterfowl nesting within either restored grassland type, please read Ryan Haffele's M.S Thesis. I will attempt to give an account of what it is really like to restore landscapes with either DNC or multi-species Native mixtures, this is what I do as a landscape restorationist and biologist. This section is simply a "conversation" from the author who has restored a few thousand acres of upland habitat to the reader who may or may not have had the pleasure.

Dense Nesting Cover (<u>Advantages</u>)

There are advantages to using the DNC mixtures, despite some documentation to the contrary as described by Haffele. Haffele describes the intensity of management of DNC which is simply untrue; DNC is the easiest mixture to physically plant, establish, and manage. Typically managers will elect to burn or hay a DNC stand about 1 – 2 times during its life cycle (normally 12 – 15 years) to retain its waterfowl nesting productivity. Another great advantage of DNC is that it performs well on soils that are laden with calcium carbonate or on saline soils where most other plants simply will not grow. A restoration project must strongly consider these abiotic factors to achieve success; it may be a waste of precious financial resources to plant many species of native vegetation that simply will not grow on marginal soils. There is no doubt that DNC is premium waterfowl nest cover as described by results gleaned in this study, and has been published as such by numerous waterfowl biologists; waterfowl nest densities in Table 2 show higher nest densities of both mallard and gadwall in DNC, and equal densities of blue-winged teal, northern pintails and northern shoveler. DNC is very robust cover which likely favors the mallard and gadwall for nesting, and this robustness may be advantageous with regards to improved waterfowl nesting success. Other unpublished fieldwork has shown that DNC will attract nesting and foraging habitat for some grassland songbirds (bobolink (*Dolichonyx oryzivorus*) are commonly observed in DNC), and DNC will also act as a surrogate habitat for numerous pollinators. DNC is relatively cheap, seed price can vary from $20 - $40 (todays price) per acre. DNC seed is easy to acquire and plant, and can be broadcast or planted in a grass drill. Because of the species present, DNC can be planted during a fall dormant window (post Oct 20) and in early spring by May 20. DNC is planted at roughly 10-11 lbs pure live seed/acre, this makes it very easy to calibrate in a grass drill and easily deliver the seed to the prepared seedbed. One must appreciate the work of the waterfowl pioneers such as Harold Duebbert, John Lokemoen, Arnold Kruse, Lewis Cowardin, Hal Kantrud and others, who saw a need to replace black dirt with upland nesting cover, and developed this mixture that could be easily established by landowners and land managers across the Prairie Pothole Region while simultaneously "saving the dirt" and "growing ducks".

Dense Nesting Cover (<u>Disadvantages</u>)

Dense nesting cover is not diverse, it contains 4 species of non-native plants; tall wheatgrass (45%), intermediate wheatgrass (25%), alfalfa (20%), yellow sweetclover (10%). Yellow sweetclover has become a significant escaped invasive species invading native rangeland so planting this species has become problematic and not compatible for managers adjacent to or near native prairie habitats. If DNC is planted today, most managers elect to eliminate sweetclover from the DNC mixtures. DNC is a short lived "semi-permanent" cover that is not intended to persist on the prairie landscape beyond 12-15 years. DNC is not considered resilient or resistant to weed invasions or invasive species. The overall carbon footprint required to manage and implement DNC would likely be higher than in a longer term Native stand. DNC species are shallower rooted plants and therefore are not considered drought tolerant leading to a lack of resilience in the face of weather oscillations. DNC is more of a mono-typical stand of 2 non-native cool season grasses and 2 forbs, it is more homogenous with regard to habitat structure and theoretically this could limit its overall wildlife value. DNC does not occupy or saturate many niches on the landscape which again leads itself to invasions from numerous other species. Excessive management of DNC will significantly limit its productivity; tall wheatgrass in particular is a short lived bunch grass which can be eliminated from a DNC stand with excessive haying or excessive early season grazing. Due to DNC's poor resistance, DNC is susceptible to smooth brome invasions which have occurred on many thousands of acres across the Dakotas. Also, alfalfa is a favorite plant of pocket gophers (*Thomomys talpoides)* which when gophers are present, the soil disturbance they create provides a microhabitat for noxious weed invasions, especially Canada thistle (*Cirsium arvense*).

Multi-species Native Upland Mixes (Natives) (<u>Advantages</u>)

While Native restoration of tallgrass prairie has been ongoing for over 25 years, the science of restoring a "mixed-grass" landscape using Native mixtures is relatively new. Major advantages of Natives (grass and forb mixtures over 20 species) is the observed species richness 3-8 years post restoration. Data from our oldest Native mixture site (20 years) have continually improved both in species richness and structure, with periodic management. Due to the occupation of numerous niches within a restoration site, it is difficult for invasive species to infiltrate a Native stand, hence suggesting that "resistance" is major defensive aspect of Native restoration success. Normally few noxious weeds and invasive grasses can occur, but to a pre-restoration level acceptable by the restorationist as successful (invasive < 10% of the stand). Due to the deep rooted nature of many of the prairie grasses, these species are well suited to undergo a wide range of climatic oscillations, hence Native stands are very resilient. Resiliency is a critical component of any functional landscape, and it may well be suited that Native stands, moving forward, are certainly a valuable tool land managers should regularly select provided funding is available. Conservation biologists routinely tout the many values of species diversity and habitat connectivity as objectives towards slowing down climate change; Native stands certainly provide those characteristics. The physical structure of Native stands is certainly more heterogeneous, and this may be one of the greatest benefits of Native habitat restorations as they pertain to a whole host of native fauna. While Native habitat did not achieve overall duck nest densities greater than DNC, there was no question that when looking at ducks as individual species, northern pintail, blue-winged teal and northern shoveler showed no difference in selecting either habitat type, and mallards and gadwall certainly used Native habitat. Therefore, Native nest cover offers perhaps a wider range of waterfowl species nest densities, more so than DNC. Perhaps the next wave of research is to investigate total faunal diversity in Native stands. This study showed that ducks will nest in either habitat type, and ancillary benefits of habitat diversity upon the prairie landscape are one of the many additional ecological services provided by this habitat restoration technique.

Multi-species Native Upland Mixes (Natives) (Disadvantages)

Native habitat restoration has few disadvantages, but perhaps the biggest is the uncertainty that this habitat type will remain resilient over time. We have been monitoring our Native restoration sites for roughly 10 years, a very short temporal period in the real world. Continual monitoring makes Natives stands more labor intensive, and there are certainly costs associated with doing so. Native stands are harder to plant due to the physical structure of some of the fluffy grass seeds. Because of this, seed mixtures are often planted at very low rates – sometimes as low as 7 lbs of pure live seed to the acre. This can be very difficult to calibrate a grass drill and it is critical that during planting, one frequently gets out and looks at the seed/soil contact and that the right rate is being applied. Soils are another limiting factor as most highly diverse mixtures may have limitations on marginal soils, especially soils high in salinity. Native plantings are excellent on high quality soils and there should be no reason not to use Natives on those sites. However, given most lands that are owned and managed by the USFWS, the land was likely sold to the government due to the unproductive nature of the soils. Establishment of Native stands is more labor intensive, although some believe that idling the stand despite the weed pressures within the first 3-5 years will result in a stand of grasses and forbs that will eventually out-compete weeds. Haffele found that duck nest failure may also be higher in Native stands than DNC, but this was only for 1 year as in other years Native stands maintained nest success well above 20%. Seed sources, seed availability and seed costs can vary wildly from year to year. Also, getting the right seed eco-type is also another potential problem as often the seed source is from a location not desirable for use in our ecoregion. These are the hard lessons we have learned over the years, but are reducing the uncertainty and more frequently achieving more success as we continue to learn from past mistakes, it is truly adaptive management in action.

Conclusion

With help from the State Wildlife Grant Program, we have attempted to answer a question, “Do multi-species Native stands produce an adequate number of waterfowl which is comparable to non-native dense nesting cover”? The answer is yes, and in doing so provides many more ecological services to our prairie landscapes. As we improve our restoration techniques, it is imperative that this information is filtered to private, State and Federal land managers across the Prairie Pothole Region. There will always be doubters of this habitat restoration technique questioning why land managers should plant anything other than habitat that maximizes waterfowl productivity. Certainly northeastern North Dakota is a highly fragmented landscape with monocultures of soybeans, corn and other agricultural commodities defining our current landscape. Our wetland densities are high however, and the amount of planted cover and the landscape low; we are grass poor in the northeast corner of North Dakota. But where opportunities abound, we have every reason to diversify our landscape while simultaneously claiming that our plant diversity work has positive outcomes for prairie nesting ducks while reducing our carbon footprint and stemming the tide of global climate change.

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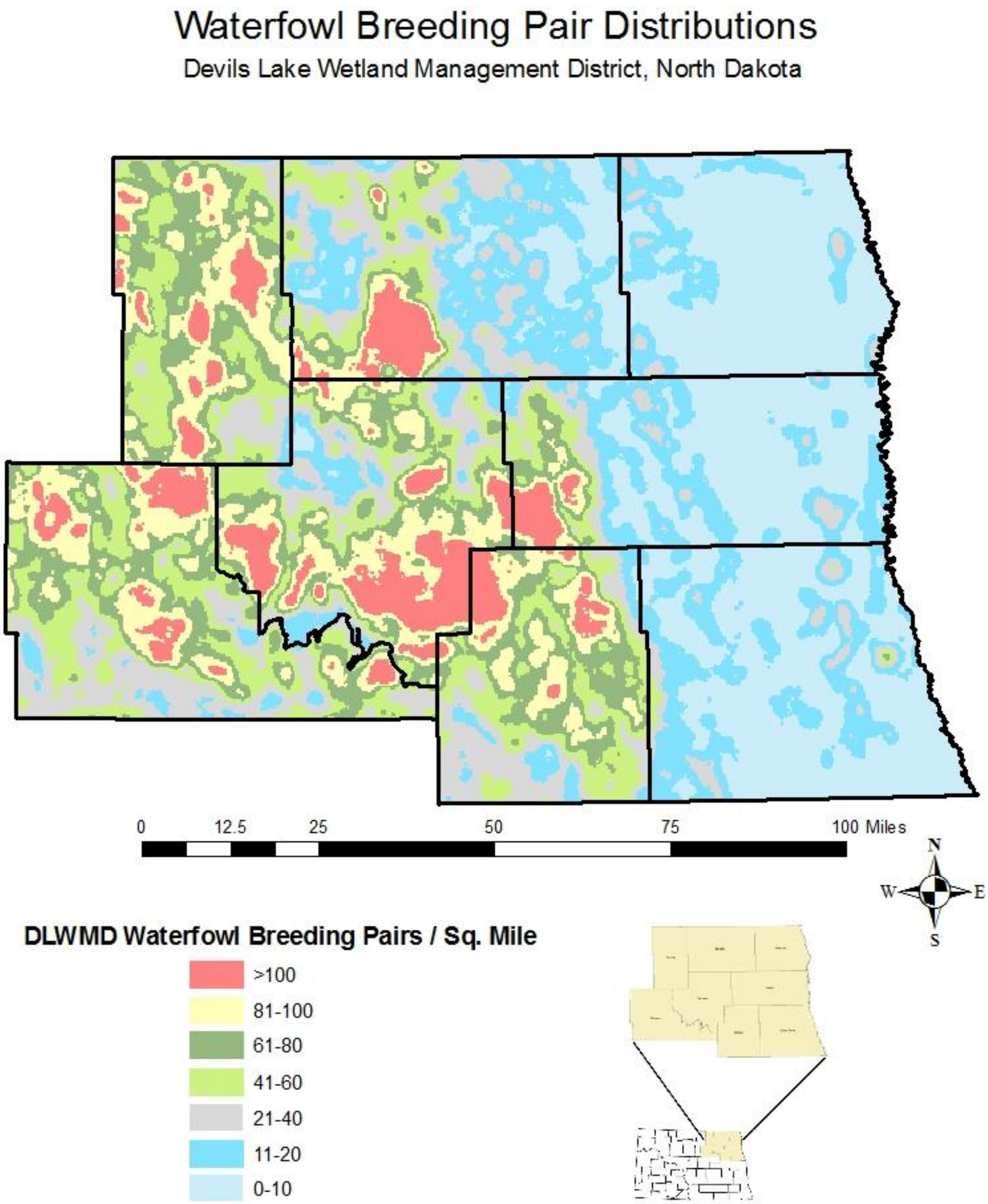

Figure 1. Devils Lake Wetland Management District Waterfowl Pair Densities.

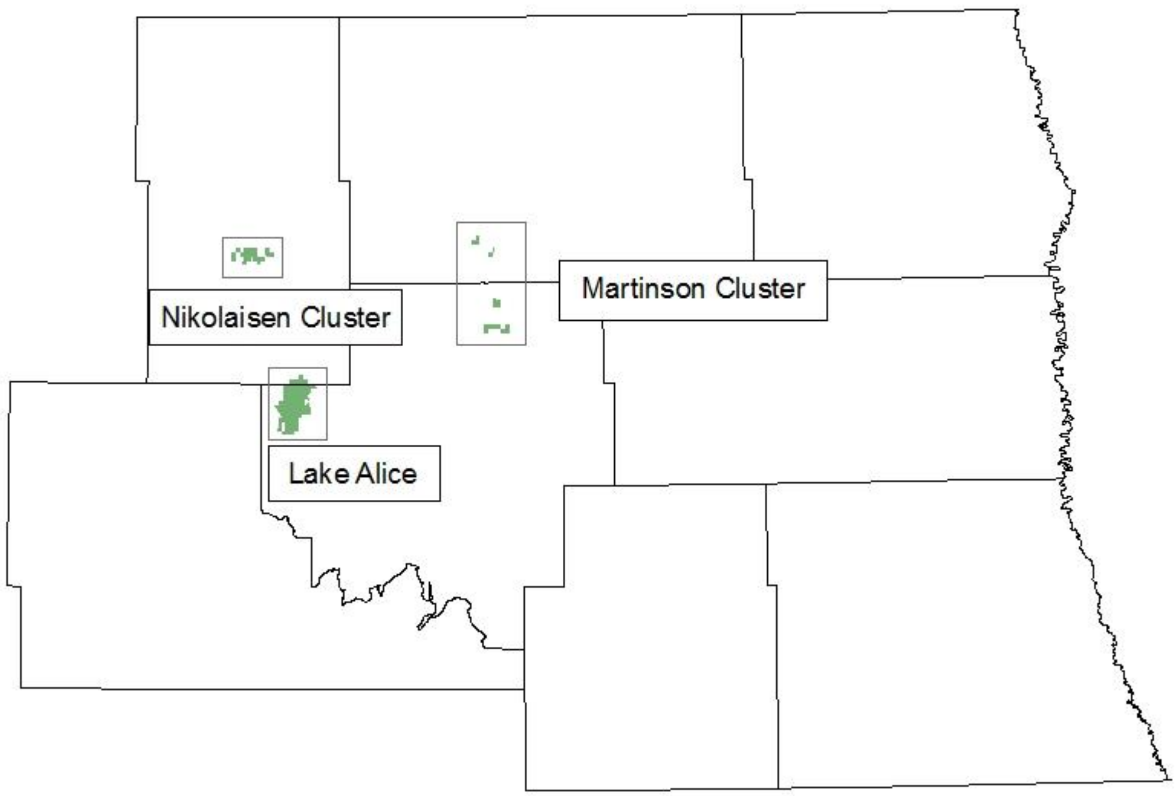

Figure 2. Map of the study sites in the Devils Lake Wetland Management District, ND.

ACRES TO BE SEEDED: 190

PURE LIVE SEED NEEDS

[1] SPECIES NO.	[2] SPECIES NAME	2 VARIETY	3 Full seeding rate pls.	4 % desired in mix	5 seeded pls. lbs/ac	6 Acres to be seeded	7 Total pls. lbs	8 Cost per pls. lb.	9 TOTAL COST
17	BIG BLUESTEM	Bison	7.9	7.0%	0.6	190	105.1	$14.00	$1,471
19	LITTLE BLUESTEM	Itasca	5.0	10.0%	0.5	190	95.0	$20.00	$1,900
20	INDIANGRASS	Tomahawk	7.9	7.0%	0.6	190	105.1	$25.00	$2,627
21	SWITCHGRASS	Dacotah	7.0	5.0%	0.4	190	66.5	$7.50	$499
24	SIDEOATS GRAMA	Killdeer	7.5	5.0%	0.4	190	71.3	$14.00	$998
35	CANADA WILDRYE	Mandan	7.5	5.0%	0.4	190	71.3	$11.00	$784
22	GREEN NEEDLEGRASS	Lodorm	7.1	12.0%	0.9	190	161.9	$7.50	$1,214
28	SLENDER WHEATGRASS	Revenue	6.5	5.0%	0.3	190	61.8	$4.00	$247
26	WESTERN WHEATGRASS	Rodan or Rosana	12.0	10.0%	1.2	190	228.0	$7.00	$1,596
39	PRAIRIE DROPSEED	Goshen	5.0	5.0%	0.3	190	47.5	$75.00	$3,563
25	BLUE GRAMA	Bad River	2.5	6.0%	0.2	190	28.5	$24.00	$684
62	PURPLE PRAIRIECLOVER		3.8	3.0%	0.1	190	21.7	$32.00	$693
63	MAX. SUNFLOWER	Medicine Crk.	1.0	2.0%	0.0	190	3.8	$40.00	$152
65	PRAIRIE CONEFLOWER		1.5	2.0%	0.0	190	5.7	$32.00	$182
47	BLACK-EYED SUSAN		0.8	2.0%	0.0	190	3.0	$25.00	$76
66	PURPLE CONEFLOWER		9.0	2.0%	0.2	190	34.2	$30.00	$1,026
69	LEWIS FLAX		3.8	2.0%	0.1	190	14.4	$25.00	$361
68	WILD BERGAMOT		0.9	2.0%	0.0	190	3.4	$85.00	$291
57	BLANKETFLOWER		7.0	2.0%	0.1	190	26.6	$45.00	$1,197
76	WHITE PRAIRIECLOVER		3.9	1.0%	0.0	190	7.4	$40.00	$296
60	SHELL-LEAF PENSTEMON		4.0	1.0%	0.0	190	7.6	$135.00	$1,026
	STIFF GOLDENROD		10.0	1.0%	0.1	190	19.0	$135.00	$2,565
	GOLDEN ALEXANDER		2.5	1.0%	0.0	190	4.8	$75.00	$356
48	CANADA MILKVETCH		4.0	1.0%	0.0	190	7.6	$45.00	$342
61	LEADPLANT		5.4	1.0%	0.1	190	10.3	$80.00	$821
				100.0%				**TOTAL ESTIMATED GRASS SEED COSTS**	**$24,967**

Figure 3. Typical planning sheet used to plan multi-species native plant mixes for upland restoration within the Devils Lake Wetland management district, North Dakota.

ADDENDUM

NESTING ECOLOGY OF DUCKS IN DENSE NESTING COVER AND RESTORED NATIVE PLANTINGS IN NORTHEASTERN NORTH DAKOTA

by

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B.S., University of Wisconsin Stevens Point, 2009

A Thesis

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Department of Zoology

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NESTING ECOLOGY OF DUCKS IN DENSE NESTING COVER AND RESTORED NATIVE PLANTINGS IN NORTHEASTERN NORTH DAKOTA

By

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Conservation efforts to increase duck production have led the United States Fish and Wildlife Service to restore grasslands with multi-species (3-5) mixtures of cool season vegetation often termed dense nesting cover (DNC). The effectiveness of DNC to increase duck production has been variable, and maintenance of the cover type is expensive. In an effort to decrease the costs of maintaining DNC and support a more diverse community of wildlife, restoration of multi-species (16-32) plantings of native plants has been explored. Understanding the mechanisms of nest site selection for nesting ducks within these plantings is important in estimating the efficiency of this cover at providing duck nesting habitat and determining appropriate management techniques. I investigated the vegetation characteristics between the 2 aforementioned cover types in the prairie pothole region of North Dakota, USA to see if native plantings provide the same vegetative structure to nesting hens as DNC. I also determined the nest density and nest success of upland nesting waterfowl in the cover types to determine if restored native plantings are providing the same nesting opportunity as DNC. Within each cover type I identified vegetation characteristics at nest sites of the 5 most common nesting species and compared them to random locations and within species to identify species specific factors in nest site selection. I located 3,524 nests (1,313 in restored-native vegetation and 2,211 in DNC) of 8 species in 2010-11. Native plantings had an average of 6.17 (SE = 1.61) nests/ha while DNC had an average of 6.71 (0.96) nests/ha. Nest densities were not different between cover types for the

5 most common nesting species. In 2010, nest success differed between cover types with restored-native plantings having 48.36% (SE = 2.4) and DNC having 42.43% (2.1) success. In 2011, restored-native planting success dropped considerably to 13.92% (1.7) while DNC success was similar to 2010 at 37.10% (1.7) The variability in nest success appeared to be impacted by late season success, as native plantings had similar success early in the nesting season, but much lower success later in the nesting season in both years. Vegetation data indicated no structural difference between cover types in 2010; however, a difference was detected during the late sampling period in 2011, with native plantings having shorter vegetation at random locations than DNC during this sampling period. In general ducks selected nest sites with greater leaf litter and denser, taller cover compared to random sites, however, vegetation density and height selection varied among species. Gadwall and mallards selected the tallest, densest vegetation, with northern pintail, blue-winged teal, and northern shovelers selecting vegetation of intermediate height and density. My results indicate native plantings are able to support similar densities of nests, but have great variability in nest success from year to year. In years with low nest success, native plantings may create an ecological sink as hens were not able to identify low quality patches and nested in similar densities despite lower success.

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INTRODUCTION

The Prairie Pothole Region (PPR), located in the north-central United States and Canada, serves as the primary breeding grounds for the majority (50-80%) of North America's waterfowl (Bellrose 1980, Batt et al. 1989). Historically dominated by mixed and tallgrass prairies (Johnson et al. 2008) and named for its extensive range of uplands with wetlands interspersed within the landscape, the PPR provides excellent loafing, roosting, and nesting sites for the reproduction of waterfowl (Kantrud and Stewart 1977). The region has become a large area of concern in recent years as 47% of wetlands have been lost in North Dakota, 35% in South Dakota, and 95% in Iowa (Dahl 1990). Also alarming is the fact that ≥ 70% of the native grasslands in the region have been converted to other uses, with 60% being converted to agriculture (USDA 2000). Each year, more native prairie is disked up and converted into agriculture. The PPR is the most intensively managed landscape in North America despite its low population (Johnson et al. 1994).

The North American Waterfowl Management Plan (NAWMP) identified the loss of grasslands in the PPR as a major cause to the decline in duck numbers and identified the region as a priority area for waterfowl (Environment Canada et al. 1986). In a recent study, Stephens et al. (2008) showed that 60,000 ha of grasslands are being converted every 10 years in the PPR, with agriculture being the predominant factor responsible for the conversions (Kantrud et al. 1989). The loss of grasslands has resulted in a loss of sufficient nesting cover and concealment from predators for nesting hens. Duck nest success fluctuates over time (Drever et al. 2004), with recent trends showing a decline at a rate of approximately 0.5% per year since 1930 (Beauchamp et al. 1996).

The remaining nesting habitat in the PPR has become extremely fragmented with tremendous losses in grasslands, and many studies have demonstrated consequences of fragmentation. Stephens et al. (2005) found nest success was positively related to the amount of grassland in a field and negatively related to the amount of fragmentation within the landscape. Arnold et al. (2007) also found higher nesting success in larger fields, which typically have less fragmentation; however, nesting density was independent of field size. Conversely, Jiminez et al. (2007) found that patch size had no effect on nest success or on nesting density and Howerter et al. (2008) found that grass and planted cover were more likely to be used for nesting sites if there was an abundance of crops in the surrounding landscape.

With fewer available nesting sites, large concentrations of nesting hens can occur in the remaining habitat. These large concentrations can exclude sexually mature individuals from nesting (Johnson et al. 1992), reducing breeding propensity. Breeding propensity (the proportion of sexually mature females in a population that lay ≥1 egg during a given breeding season; Lindstrom et al. 2006), is an important component to the population dynamics of waterfowl (Johnson et al. 1992). Martin et al. (2009) found reduced breeding propensity in radio-marked lesser scaup (*Aythya affinis*). Coluccy et al. (2008) estimated the breeding propensity for mallards (*Anas platyrhynchos*) in the Great Lakes to be about 84%, whereas Sedinger et al. (1995) indicated not all sexually mature black brants (*Branta bernicla*) nested. Petrie et al. (2000) suggested that a difference in breeding propensity was the cause for divergent population trends in mallards and black ducks (*A. rubripes*).

Because of the negative consequences of fragmentation, conservation efforts like the Conservation Reserve Program (CRP, USDA) have been established to alleviate the amount of fragmentation that has occurred and reduce the effects of losing grasslands (i.e., erosion). The

CRP program has created thousands of acres of suitable nesting habitat for waterfowl, and produced an average of ~ 2 million more recruits (Reynolds et al. 2001). The temporary nature of CRP is problematic, however, as most contracts only convert cover for 10-15 years and then the land can be converted back into agricultural production, thus if funding for this program is lost, the majority of habitat will also be lost.

Another conservation measure that was directly related to waterfowl was the Small Wetlands Program which allowed the acquisition and establishment of Waterfowl Production Areas (WPA; USFWS 2009). This program enabled the United States Fish and Wildlife Service (USFWS) to help duck production by buying important wetland and upland habitat for waterfowl in the PPR. Most of these acquisitions contained cultivated farmland that was seeded into upland habitat. Once purchased, these habitats remain the property of USFWS, eliminating the risk of conversion back into agriculture. Emery et al. (2005) found that planted cover was the best management strategy to enhance early-season nest success. These early plantings were composed mostly of a mixture of intermediate wheatgrass (*Thinopyrum intermedium*), tall wheatgrass (*Thinopyrum ponticum*), alfalfa (*Medicago sativa*), and sweet clovers (*Melilotus spp.*), all of which are introduced species (Higgins and Barker 1982). These seed mixtures, referred to as dense nesting cover (DNC), reach a maximum growth after 2-4 years (Higgins and Barker 1982) but degrade after approximately 10 years forcing a cyclic management of farming for 2-3 years, seeding with a DNC mixture and monitoring with minimal management of mowing/haying for 10-15 years when it is then burned and restored to agriculture for 2-3 years prior to reseeding in DNC. This cycle is continuous, increasing the cost of management for DNC.

New conservation efforts are aimed at re-seeding previously cultivated lands into a species-rich mixture (16-32 spp.) of native grasses and forbs on USFWS land in the eastern Drift

Prairie of North Dakota as opposed to the monotypic DNC fields of introduced species (C. Dixon, USFWS, personal communication). These efforts have a high and sometimes variable cost ($120-$300/acre) relative to DNC seeding ($20-$30/acres; C. Dixon, USFWS, personal communication) but persist for many years with proper management, thus eliminating reseeding costs that occur with DNC (Lokemoen 1984). Previous attempts to replace DNC with native vegetation have achieved mixed results. Most attempts used only 4-6 species and were quickly invaded with exotic species of vegetation (Blankespoor 1980). Using species-rich mixtures of native plants in restoration efforts may help prevent the invasion of noxious weeds that degrade the stand (Tilman 1997, Sheley and Half 2006). Diverse communities use resources more completely, leaving fewer resources for invaders and reducing community invasibility (Case 1990, Tilman 1997, Jacobs and Sheley 1999). The saturation rate (productivity declines when diversity reaches a certain level) for grasses and forbs in a North Dakota study was anywhere from 16-32 species, suggesting that a wide range of species should be used in restoration efforts (Guo et al. 2006).

Although prairie restorations are implemented to replace native prairies, modification of soils, lack of diversity in seed mixtures, genetic differentiation between local communities and transplanted seed mixtures (Hufford and Mazer 2003) as well as other factors prevent these restorations from duplicating the vegetative diversity and structure of remnant native prairies. Thus, although upland nesting ducks in the prairie pothole region have evolved to nest in native prairies, information to determine if these restorations duplicate natural prairies adequate to support historic densities of upland nesting ducks is still limited. The available literature indicates sites with seeded cover that was dominant or codominant with native species had as high or higher nest initiation rates than sites where natives were absent, however, fields with native species contained a large proportion (often the majority of cover) of exotic species mixed with the native species (Klett et al.1984).

Recreating habitats that allow adaptive selection of safe nesting sites to avoid predators is critical for population dynamics in ducks. Predation is the primary cause of nest failure and adult hen mortality during the breeding season (Ricklefs 1969, Sargeant 1972, Greenwood et al. 1995) creating strong selective pressure to select optimal nest sites. This selective pressure creates a trade-off between adult hen and nest survival (Götmark et al. 1995). To maximize hen survival, hens should select nest sites allowing easy predator detection, usually resulting in less cover. However, since eggs are unable to escape predation, nest survival should be maximized by increasing concealment and cover. These selective pressures should drive hens to select nest sites that have intermediate cover and density to maximize hen and nest survival. Understanding the vegetative characteristics hens select for in a nest site is important in determining the proper management practices of habitats to maximize production.

I determined the nest density and success, vegetative characteristics between cover types, as well as species-specific nest site characteristics for upland nesting ducks. In Chapter 1, I compare the nest density and success of upland nesting ducks in DNC and restored-native plantings in the Devils Lake Wetland Management District (DLWMD) as well as structural vegetation characteristics between the 2 cover types at random locations. In Chapter 2, I tested for variation in vegetation characteristics among random points and nest sites of upland nesting ducks.

Study Area

The eastern Drift Prairie of North Dakota is located in the heart of the U.S. PPR and is an important area for duck production. The Drift Prairie once made up 88% of the 37.31 million acres of native prairie in the state, which was approximately 35% of all northern mixed grass prairies in the United States (Conner et al. 2001). Predominant native vegetation in the area include: green needlegrass (*Nasella viridula*), little bluestem (*Schizachyrium scoparium*), western wheatgrass (*Pascopyrum smithii*), purple prairie clover (*Dalea purpurea*), prairie rose (*Rosa arkansana*), and lead plant (*Amorpha canescens*; Hagen et al. 2005).

The landscape and land uses in the region have changed drastically since European settlement (Conner et al. 2001). Today, more than 70% of native prairies have been converted to other land uses, predominantly agriculture (60%; Conner et al. 2001). Recently, the greatest losses of native prairies have come in the eastern and northeastern areas of North Dakota, where the majority of the U.S. PPR lies (Conner et al. 2001). Large wetland drainage efforts have also occurred in the state as 47% of all wetlands have been drained since European settlement (Dahl 1990).

The large portion of the Drift Prairie in North Dakota is located in the DLWMD. The DLWMD was established in 1962 managing important upland and wetland habitat that is needed by waterfowl for nesting and feeding during the Spring and Summer (USFWS 2009). To provide this crucial habitat for waterfowl, the DLWMD manages 373 tracts of WPA’s covering 51,182 acres, 3 National Wildlife Refuges, as well as thousands of acres of wetland and grassland easements (C. Dixon, USFWS, personal communication). These numerous tracts of land support 60-100 pairs of breeding ducks per square mile (Figure 1, After Niemuth et al. 2008).

The DLWMD started restoring fields with native multi-species mixtures in 2005. The main species found in these mixtures have been: western wheatgrass, green needlegrass, big bluestem (*Andropogon gerardii*), little bluestem, maximilian sunflower (*Helianthus maximiliani*), Canada milkvetch (*Astragalus canadensis*), and yellow coneflower (*Ratibida* *pinnata*). All seeds were purchased as cultivars and seeding protocols followed the Herbaceous Vegetation Establishment Guide for North Dakota (NRCS 2010). Selected fields for native plantings were based on priority for DLWMD, with fields being selected in areas with larger tracts of grasslands in the immediate area to prevent isolation of plantings. Soil tests were performed on some of the fields to determine nutrient levels; however, no soil modification occurred on any field (C. Dixon, USFWS, personal communication). Establishing the native plantings before noxious weeds can invade has been the biggest challenge. Smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) also readily invade new plantings reducing the quality of the native establishment (C. Dixon, USFWS, personal communication).

Staff at DLWMD is primarily managing these native plantings by using prescribed burning. Grazing will also be implemented in the future as a management tool. These management practices are very cost effective as opposed to management required for DNC plantings. Dense nesting cover plantings are considered a semi-permanent cover (Higgins and Barker 1982, Duebbert and Frank 1984, Lokemoen 1984) and are typically managed by mowing, haying, fire, and are eventually cultivated, farmed, and then reseeded. The native plantings are designed to survive perpetually with the management of fire and grazing, thus, having fewer fiscal and ecological costs in the long term (C. Dixon, USFWS, personal communication).

CHAPTER 1

NEST DENSITY AND SUCCESS IN RESTORED NATIVE AND DENSE NESTING COVER PLANTINGS

INTRODUCTION

The breeding period is most critical for temperate nesting duck population dynamics as most mortality and all production occurs (Johnson et al. 1992). In the PPR of the United States, changes in populations are thought to be most sensitive to changes in nest success (Hoekman et al. 2002*b*). Recent studies have shown that nest success has been declining over time (Beauchamp et al. 1996) with the loss of grasslands thought to be the primary cause (Environment Canada et al. 1986). Researchers and managers have focused on increasing nest success since the establishment of the NAWMP, with the primary strategy to increase upland nesting cover. Despite efforts, grasslands in the PPR continue to be lost at significant rates (Higgins et al. 2002, Stephens et al. 2008).

The changing landscape from native prairie to other land uses across most of the breeding range for temperate-nesting ducks has resulted in fewer available nesting sites. This altered landscape, in addition to the removal of top predators like gray wolves (*Canis lupis*), has changed predator communities allowing meso-predators like striped skunks (*Mephitis mephitis*) and red fox (*Vulpes vulpes*), which efficiently forage for duck nests, to become the dominant predators, augmenting the negative effect of habitat loss on nest success (Sargeant et al. 1993, Sovada et al. 1995). Nesting cover is thought to decrease predation of nests by providing concealment from predators, establishing scent and visual barriers, and impeding the movement of mammalian predators (Duebbert and Kantrud 1974, Livezey 1981*a*, Hines and Mitchell 1983).

Most management to date has involved restoring large stands of tall, dense introduced cool season vegetation called DNC on the landscape to provide adequate cover for nesting. Introduced species are often used to restore habitats due to their widespread adaptability to grow in numerous environments (Pellant and Monsen 1993). Research has shown that tall planted cover was preferred by nesting hens over other vegetation types (Klett et al. 1988) with large stands of cover benefiting ducks more than isolated patches in agricultural land (Ball et al. 1995).

DNC provides suitable nesting cover for ducks in agricultural areas (Duebbert 1969, Higgins 1977) and can support large densities of nesting hens, leading managers to believe it is high quality habitat. High species densities, however, do not always correlate to high quality habitat as fitness may be reduced in these habitats (Weller 1979, Hill 1984, Sugden and Beyersbergen 1986, Vickery et al. 1992, Larivière and Messier 1998). To determine the quality of habitat it is important to look at both density and reproductive success within the habitat (Van Horne 1983). When applying this methodology to DNC it has been shown, despite its attractiveness to nesting hens, nest success has been variable (McKinnon and Duncan 1999) with many studies reporting success rates below the 15-20% believed to be necessary to maintain duck populations (Cowardin et al. 1985).

Maintaining DNC to provide suitable nesting habitat is expensive requiring replanting approximately every 10 years with 2-3 years of agricultural production between plantings (Lokemoen 1984). The cyclic management regime associated with DNC increases the cost of establishment and maintenance, reducing limited funds available for management activities. Due to the considerable cost of DNC as well as changing social values and enhanced ecological knowledge (Richards et al. 1998), establishing upland cover with native species designed to survive perpetually is being explored.

The main goal of restoration is to create a self-supporting ecosystem resilient to perturbation without further assistance (Urbanska et al. 1997, SER 2004). Restoring grasslands into DNC deviates from this goal, as reseeding is almost always necessary as the stand degrades (Higgins and Barker 1982). Using native species that are adapted to the local environment can eliminate the reseeding process if a natural disturbance regime is reintroduced to the system (Trowbridge 2007). Establishment of native grasses in restoration efforts holds many benefits over introduced species. While native grasses tend to take longer to establish, once established they hold and recycle nutrients more efficiently, maintain biodiversity on the landscape, and create a more heterogeneous landscape compared to introduced species (Menke 1992). Restored native prairies have also been shown to serve as a successful method to control invasive, noxious species by outcompeting and preventing their spread (Blumenthal et al. 2003, 2005). The 1997 Refuge Improvement Act mandates that National Wildlife Refuge lands be administered in a way that strives to provide biological integrity, diversity, and environmental health. This is another impetus to consider seeding native plants rather than DNC on refuge lands. (Schroeder et al. 2004).

While DNC provides sufficient nesting cover for hens, it creates a very homogenous landscape, often benefiting species like mallards and gadwalls (*Anas strepera*) that prefer thick, dense cover but serving modest functions for species that prefer sparse vegetation like northern pintails (*Anas acuta*), blue-winged teal (*Anas discors*) and various grassland songbirds (Gilbert et al. 1996, McKinnon and Duncan 1999). Restoring grasslands into diverse mixtures of native plants will likely increase heterogeneity on the landscape providing better habitat for an assortment of species. Recent research has shown that native prairie and warm-season mixtures of native plants have higher bird richness than DNC, with warm-season mixtures having similar richness to native prairie (Bakker and Higgins 2009).

As aforementioned, vegetation characteristics in a field can affect success and densities of upland-nesting ducks (Livezey 1981*a*, Hines and Mitchell 1983), although the relative value of DNC, native cool season grasses, and native prairie is still unresolved. Rodriguez (1984) indicated that the nesting density was higher in DNC fields than native cool-season grass fields, but hatching success was not different. Likewise, Higgins et al. (1992) found higher duck production on DNC than remnant native prairie and also found the DNC to produce 3 times as many ducklings per unit area. Kaiser et al. (1979) found more nests of blue-winged teal in tame communities (introduced species) than native, but higher nest success and more nests per hectare in native communities. Arnold et al. (2007) found no difference between native and tame fields when looking at how waterfowl used DNC in the Canadian Parklands.

With a knowledge gap existing in the value between DNC and restored native plantings, my objective was to compare nest success and density between the 2 cover types. I predict that restored native plantings will provide sufficient nesting cover for hens, resulting in similar success and density as DNC.

METHODS

Study Area

My study area was located in the Devils Lake Wetland Management District in northeastern North Dakota. Study fields were located in Ramsey, Towner, and Cavalier counties (Figure 2). I collected data on 14 study fields, 7 planted in DNC and 7 planted with multi-species mixtures of native plants (hereafter: native) For a complete list of species planted in each field see Appendix 1-7. Each field was assigned to a cluster based on geographic location (Table 1).

The Lake Alice cluster was located in northwestern Ramsey County and consists of 3 fields, 2 of which were planted with native species (L.A. North and Toilet). The native fields were seeded with 7 species of warm-season grasses, 3 cool-season grasses and 12 species of forbs. The DNC field was seeded with 2 cool-season grasses and 2 forbs. Both native fields were mowed after the first growing season and then spot-mowed in 2010 to control invasive species. No management has occurred on the DNC field.

The Martinson cluster was located in northeast Ramsey and Southeast Cavalier counties, containing 5 fields; 3 DNC (Martinson DNC, Phil Aus, and Weaver) and 2 multi-species native (Martinson Native and Dahl). The Martinson Native field was seeded with 8 warm-season grasses, 3 cool-season grasses, and 12 forbs and was mowed after the first growing season. Currently, a large invasion of absinth wormwood (*Artemisia absinthium*) dominates the field. Dahl was seeded with 6 warm-season grasses (predominantly big bluestem) and 1 cool-season grass with forb seeds being spread by hand after grasses had been established. The eastern ¼ of the field was burned in 1998. DNC fields were seeded with 2 cool-season grasses and 2 forbs. Phil Aus was managed by fire in 1998 and mowed in 2004, 2006, and partially mowed in 2010. The western portion of Weaver was burned in 2006 by an accidental fire. Both Phil Aus and Weaver fields have degraded over time and are dominated by Kentucky bluegrass and smooth brome. The other DNC, Martinson was burned in 1998 in an arson fire.

The Nikolaisen cluster was located in eastern Towner County and contains 6 fields, 3 multi-species native (Register West, Cami, and Halvorson) and 3 DNC (Nik Central, Nik South, and Nik Southeast). Register West was seeded with 5 warm-season grasses, 5 cool-season grasses, and 7 forbs. The field was hayed in July of 2009 and 2010 and treated with Milestone at 7 oz/acres to control an invasion of canada thistle (*Cirsium arvense*). Cami was seeded with 7 warm-season grasses, 5 cool-season grasses, and 15 forbs. The field was burned in 2008 and grazed from July 1 to August 10 in 2010. Halvorson was seeded with 2 species of warm-season grasses, 2 species of cool-season grasses, and various forbs. The field was hayed in 1986 and 1987 and grazed using a 3 cell rotation in 2007, 2008, and 2009. The DNC fields were seeded with 2 cool-season grasses and 2 forbs. Nik Central was grazed at the same time as Cami in 2010. Nik South was managed by haying in 2008 and 2010. Nik Southeast was grazed in 2008 and 2009.

Field Sampling

To compare vegetative structure between habitat types, I recorded vegetation data at random locations within each field, with 1 random point being assigned for every 2 ha of the field to ensure sampling throughout the entire field. I overlaid each field with a grid composed of 2 ha blocks and generated random points in each block using Hawths Tools for ArcMap 9.3 (Environmental Systems Research Institute [ESRI], Redlands, California, USA). This resulted in a total of 266 random points; 126 in restored-native plantings and 140 in DNC. To guarantee accuracy of the placement of random points throughout the study, points were marked with orange stakechasers which were found in subsequent years using a Trimble GPS unit. I sampled points 3-m south of the stakechaser to prevent disturbance of the vegetation while searching for the stakechasers.

I collected data in two time periods of each study season. The first data were collected in late April before nest searching began to characterize vegetation structure when early nesting species initiated their nests. The second data collection occurred in the middle of June, characterizing vegetation structure for hens who initiated nests late in the nesting season. I determined the same vegetation characteristics during both sampling periods: vegetation height, visual obstruction (hereafter cover density), and litter depth. I used Robel poles to determine the cover density and vegetation height. Cover density readings were taken in the 4 cardinal directions at a distance of 4 m and a height of 1 m by marking a point on the Robel pole where vegetation obscures the pole 100%. These readings gave cover density measurements that are strongly related to the amount of vegetation present (Robel et al. 1970), thus giving an indication to the structure available for hens to nest in. I averaged the 4 readings to obtain an overall estimate of the cover density around the nest. I determined the vegetation height to be the point on the Robel pole that > 80% of vegetation was growing below (Fisher and Davis 2010). I measured the litter depth by measuring the height of dead vegetation that forms a mat layer on the ground using a standard ruler in cm (Schneider 1998). To be classified as litter, vegetation had to be lying on the ground, as I did not measure standing residual vegetation as litter. Vegetation litter provides a suitable nesting substrate for hens and may be important for the concealment and success of nests (Bue et al. 1952, Duebbert 1969, Gjersing 1975, Winter 1999).

To test for differences in nesting density and success, I systematically searched all upland cover in a field for nests starting in the first week of May and concluded searching the first week of July. Each field was searched 7 times on 8 day intervals. Nests were located using teams of 2 dragging a 50 m cable-chain behind all-terrain vehicles (Klett et al. 1986). Speeds were kept between 3-8 km/h by keeping ATV's in low gear allowing drivers to stay in a straight line and watch the cable drag (Klett et al. 1986). Dragging at speeds faster than 8 km/h increases the likelihood of the chain passing over a nest without flushing the hen. I searched for nests between 0700 and 1400 to maximize the probability of the hen being on the nest (Gloutney et al. 1993). I alternated the starting location of fields for each drag to prevent the same area of the field being searched during the same time of day, reducing the possibility of a hen being on an incubation break during subsequent searches. I marked each nest found with a 1-m wooden lathe painted white with red on the top to allow easy visualization in the field by searchers. The wooden lathe was placed 10-m north of the nest and numbered to give each nest its own unique identification. A metal rod painted orange was placed on the north rim of the nest bowl at each nest to assist with relocation. Nests were monitored on 5 day intervals until fate was determined (e.g., successful, depredated, abandoned). I determined the clutch size and incubation status at each visit. Incubation status was determined with a simple field candler (Weller 1956) made from 1-inch radiator hose. I recorded the date, field, species and Universal Transverse Mercator coordinates for each nest. In 2010, I monitored the first 100 nests found in each field, then randomly selected 20 nests from each subsequent search for fields with > 100 nests due to time constraint. In 2011, I monitored all nests found. After each visit, the nests were covered using material from the nest and a marker in the form of an X made out of vegetation was placed on top. If the X was found undisturbed on the next visit, I considered it abandoned due to investigator disturbance and censored it from survival analysis.

Statistics Analysis

To determine if variation in vegetation type led to differences in cover density, litter depth, and vegetation height between cover types, I analyzed the data using 3 mixed model ANOVAs in SAS 9.2 (PROC MIXED; SAS 9.2 SAS Institute Inc., Cary, North Carolina, USA, 2008) for each time period separately. Cover density, litter depth, and vegetation height were the dependent variables, cover type was the independent variable and cluster was included as a random effect. I included cluster to control for any variation that may have occurred due to geographic differences.

To compare daily nest survival and nest success between habitat types I used the Dinsmore model in Program Mark (White and Burnham 1999, Dinsmore et al. 2002, McPherson et al. 2003) to estimate daily survival rates (DSR) of nests for each field. I assumed a 35-day exposure period (Klett et al. 1986) to convert DSR to point estimates of nest success and estimated the standard error of point estimates using the Delta Method. To determine if there is evidence for a treatment effect on daily survival rate, I compared a model that included cover type to a model that excluded cover type using Akaike Information Criteria (AIC, Akaike 1973). I also tested for a treatment effect of nest initiation date on DSR in each cover type by comparing the additive and interacting models of initiation date and cover type.

To compare nesting density between habitat types, I estimated the density of nests in each field by taking the total number of nests I found in each field and dividing it by the DSR of the field raised to the power of the average age of the nests found in that field ($\frac{\#\ nests\ in\ field}{DSR^{avg\ ag\ of\ nest\ found\ in\ field}}$). I used a mixed model ANOVA (PROC Mixed; SAS 9.2 SAS Institute Inc., Cary, North Carolina, USA, 2008) with my density estimates for each field as the dependent variable, cover type as the independent variables, the amount of wetland shoreline as a covariate and cluster as the random effect. Other studies have found that breeding bird densities are related to wetland densities on the breeding grounds (Krapu et al. 1983); therefore I classified wetlands according to Stewart and Kantrud (1971) and measured the amount of temporary, seasonal, semi-permanent, and total shoreline in each field. I used these measurements to account for any differences in wetland abundance that may have influenced densities of nesting hens.

To determine if species-specific nesting densities varied between cover types, I used a mixed model ANOVA (Proc mixed SAS 9.2 SAS Institute Inc., Cary, North Carolina, USA, 2008) with species and cover type as the independent variables, density as the dependent variable and cluster as a random effect. I determined species density using the same formula as field density.

RESULTS

I analyzed data from 274 random points located within the 14 study fields in 2010. Vegetation characteristics were not different between cover types during either sampling period (Table 2). In the fall of 2010 a variety of management actions occurred on 6 of 14 study fields. Two of the fields (1 native and 1 DNC) were grazed with cattle from 1 July to 10 August. Two native fields were "clipped" where specific areas within a field with nuisance and exotic species were mowed while the rest of the field was left unmanaged. The other 2 (1 native and 1 DNC) managed fields were hayed. These fields were excluded from all analysis in 2011.

In 2011 I analyzed 153 random points from 8 fields (Table 3), as I excluded managed fields from analysis. In the early sampling period, there was no difference ($F_{1,5} = 0.03$, $p = 0.87$) in height between the cover types, as native plantings had an average height of 8.94 ± 0.85 cm and DNC plantings had a height of 10.22 ± 1.61 cm. There was also no difference ($F_{1,5} = 0.82$, $p = 0.41$) in cover density between cover types with native plantings having an average obstruction of 5.99 ± 0.76 cm and DNC averaging 8.40 ± 1.66 cm. Litter depth was different ($F_{1,6} = 8.33$, $p = 0.03$) between cover types as native plantings had an average depth of 2.44 ± 0.37 cm and DNC had an average of 5.00 ± 0.63 cm.

During the late sampling period, there was a difference in height ($F_{1,5} = 35.30$, $p < 0.01$) between cover types with native plantings having an average height of 19.35 ± 2.69 cm and DNC having an average height of 33.65 ± 2.97 cm. The difference in cover density was approaching statistical significance ($F_{1,5} = 4.15$, $p = 0.10$), as native plantings had an average cover density of 13.01 ± 2.68 cm while DNC had an average of 23.63 ± 4.41 cm.

I located 3,524 nests of 8 species during the 2010-11 field seasons (Table 4). Of these nests, I used 2,594 to determine the success rate for each field. The nests not used in the analysis were censored due to investigator damage, disturbance, or they were not randomly selected to be monitored. The 8 different species found were: gadwall (1,042 nests), blue-winged teal (963 nests; hereafter teal), northern shoveler (*Anas clypeata*; 553 nests; hereafter shoveler), mallard (517 nests), northern pintail (285 nests; hereafter pintail) lesser scaup (*Aythya affinis*; 130 nests), green-winged teal (*Anas crecca*; 17), and American wigeon (*Anas Americana*; 17 nests).

Nest density varied widely between fields ranging from 1.09 nests/ha to 15.06 nests/ha in 2010 and 1.19 nests/ha to 12.05 nests/ha in 2011 (Table 5). Cover type did not have an effect on density ($F_{1,19} = 0.20$, $p = 0.66$; Table 6), as DNC plantings had an average density of 6.71 (SE = 0.96) nests/ha and native plantings had 6.17 (SE = 1.61) nests/ha for both years combined. The cluster*type interaction was significant ($F_{2,8} = 4.59$, $p = 0.05$) in 2010, however no clear pattern was shown as density was higher for native plantings in the Lake Alice cluster while the other 2 clusters had higher densities for DNC (Figure 3). The amount of shoreline in each field did not have an effect on nest density ($F_{1,13}= 1.60$, $p = 0.25$). However, the amount of temporary shoreline was marginally significant ($F_{1,13} = 5.00$, $p = 0.06$) in 2010.

Nest densities were not different between cover types for any species ($F_{4,99} = 0.16$, $p=0.96$; Table 7). Mallard densities averaged 0.99 ± 0.25 nests/ha in DNC and 0.90 ± 0.46 nests/ha in native plantings for both years combined. Pintails had the lowest densities at 0.58 ± 0.10 and 0.45 ± 0.12 nests/ha for DNC and native plantings respectively. Shovelers averaged 1.03 ± 0.10 and 0.78 ± 0.12 nests/ha in DNC and native plantings. Gadwall had an average density of 2.00 ± 0.42 nests/ha in DNC and 1.55 ± 0.58 nests/ha in native plantings. Teal densities in DNC were 1.84 ± 0.37 nests/ha, while native plantings had an average of 1.76 ± 0.46 nests/ha.

Overall nest success for all fields was 45.05% (SE= 1.6) in 2010 and 29.89% (1.3) in 2011. Nest success was variable across fields, ranging from 12.78% (3.1) to 73.92% (4.9) in 2010 and 3.15% (1.6) to 49.46% (4.5) in 2011 (Table 8). In 2010, native plantings had a success rate of 48.36% (2.4), while DNC plantings had a success of 42.43% (2.1). In 2011, the most parsimonious model included a treatment effect of cover type on success with nest success in native plantings dropping to 13.92% (1.7) while DNC was comparable to 2010 at 37.10% (1.7). AICc showed support for a treatment effect of cover type on success as the model including cover type was more parsimonious than the model excluding cover type (Table 9). Additionally, there was support for an interaction between cover type and nest initiation date, as the interactive model was 5 AIC points better than the additive model (Table 10).

DISCUSSION

Vegetative Structure Between Cover Types

My results indicate that native plantings are able to provide the same vegetation height and obstruction as DNC early in the nesting season. Results were variable later in the nesting season as structural characteristics were similar between cover types in 2010 but DNC plantings had taller vegetation in 2011. Litter depths were similar between cover types in 2010 but DNC had more litter in 2011. My findings contradict previous studies that have shown native mixes with a component of warm-season species to have taller vegetation than cool-season mixes (Bakker and Higgins 2009), but corroborate studies that have found shallower litter depth in warm-season fields (McCoy et al. 2001).

The difference in litter depth in 2011 may be a result of the species composition in the fields. The native plantings included warm-season species which are known to remain upright over winter despite snowpack, unlike cool-season species (King and Savidge 1995, Delisle and Savidge 1997). In 2010, temperatures warmed up rapidly causing rapid snow melt, increasing surface flows of water that knocked down the majority of standing residual vegetation creating greater litter depths in all fields. In 2011, temperatures gradually increased and snow melt was slower which decreased surface flows. With decreased surface flows, fewer warm-season species may have been knocked down reducing the amount of litter in native plantings while DNC had more litter due to lodging of cool-season species under the snowpack.

My results also indicated vegetation was taller in DNC during the late 2011 sampling period. One hypothesis for the difference in height in the late sampling period of 2011 is cold spring temperatures had a disparate influence on warm-season grasses. In 2010, an early spring occurred with April and May temperatures being the warmest since 1981. Conversely, in 2011 temperatures were 10 degrees cooler with above normal precipitation (NOAA 2011), which may have limited growth of warm-season plants. Warm-season species (C_4) typically begin active growth in early summer when temperatures warm up compared to cool-season species (C3) that actively grow in the wetter, cooler spring (Black 1971). With the late warm up, the warm-season species may have not started active growth until later in the season resulting in a difference of height from the cool-season dominated DNC plantings at the time of the late sampling. While native plantings did include a cool-season component providing earlier growth in these fields, they did not appear to provide the same cover as the cool-season species in DNC. This may be due to DNC being composed completely of cool-season species, while they were not as predominant in the native seed mixtures.

Nest Densities Between Cover Types

In general, densities on my study fields were much higher than other studies. Arnold et al. (2007) found 1.51 nests/ha in the Canadian Parklands region during the mid to late 1990s on fields planted with DNC. Devries and Armstrong (2011) found nest densities of 1.33 nests/ha, also in the Canadian Parklands. McKinnon and Duncan (1999) estimated densities ranging from 1.1 to 1.4 nests/ha in DNC of southern Saskatchewan, Canada. Klett et al. (1984) estimated densities of 0.9 and 1.5 nests/ha for DNC and warm season plantings, respectively. The greater number of nests per hectare on my study sites was most likely due to the highly fragmented landscape that is dominated by agriculture. Agricultural land is less attractive to nesting ducks (Higgins 1977), making the isolated patches of grasslands highly attractive. With large densities of breeding pairs in the area (Figure 1), it is likely that the majority of hens were attracted to the limited amount of grassland cover increasing the density of nests.

The effectiveness of native plantings to provide the same nesting densities as DNC has been unresolved. Rodriguez (1984) found higher densities in DNC than native cool season grasses. Likewise, Kaiser et al. (1979) found more nests in tame communities than native communities. Rohlfing (2004) found higher densities in DNC later in the nesting season, but no difference early in the nesting season. Other studies have shown no difference between DNC and native plantings (Klett et al. 1984, Rock 2006, Arnold et al. 2007). These studies focused on monocultural native stands that were seeded with all warm-season or all cool-season species. A recent study in South Dakota showed nest densities to be lower in multi-species mixtures of native grasses and introduced legumes compared to monocultural stands of DNC and warm-season species (Rock 2006). The native mixtures in my study indicate plant mixtures that provide a variety of warm and cool-season species are able to sustain the same duck nest densities as DNC.

Providing a diverse habitat containing multiple species of cool and warm-season grasses as well as forbs provides greater benefit to avian species than monocultural stands (Sample 1989). Cool season grasses start actively growing in the early spring, providing cover and concealment early in the nesting season. Once temperatures warm up later in the spring and early summer, these grasses become dormant and warm-season grasses start actively growing (Black 1971), providing additional cover and concealment. Forbs and legumes provide structural diversity within the stand as they tend to branch out laterally, helping to restrict mammalian predator movement (Bowman and Harris 1980).

One issue with DNC is the belief that it serves greater benefits for species that prefer tall, thick, dense cover like mallards and gadwalls while having limited benefits to other species (Gilbert et al. 1996, McKinnon and Duncan 1999). Native mixtures have been found to benefit a greater array of species, especially teal, pintails, and shovelers (Keith 1961, Kaiser et al. 1979). My results showed the majority of species nested in slightly higher densities in DNC; however no comparisons were statistically significant. Gadwalls nested in the highest density of any species in DNC, while teal nested in the highest density in native plantings. In contrast to previous findings, it appears that DNC provides equivalent benefits to species that nest in both dense and sparse cover and native plantings are able to provide comparable benefits as DNC for all species.

Despite a lack of significant differences in vegetation characteristics between cover types during all sampling periods, trends in vegetation characteristics and species-specific nest densities suggest the differences may be biologically important. Vegetation tended to be taller and denser with deeper litter in DNC. Additionally, species-specific nest densities tended to be greater in DNC, suggesting the slight discrepancies in vegetation characteristics may be important. Despite these differences, it is likely other benefits of native plantings, like increased faunal diversity, may outweigh the non-significant differences in species-specific nesting densities between cover types.

Nest Success Between Cover Types

Overall nest success during my study was similar to other studies in the region during the same time period (Pieron and Rohwer 2010). Success declined in 2011, but was still greater than the 15% threshold thought to be needed to maintain duck populations (Cowardin and Johnson 1979, Cowardin et al. 1985). Nest success has been shown to vary across time in relation to predator abundance and pond densities (Drever et al. 2004). May pond counts indicated a 3% decrease for the region in 2011 compared to 2010, but were still 115% above the long term average (USFWS 2011). This decrease in pond counts did not likely have an effect on nest success. The decline in success was more likely due to an increase in nest predators within the region (Figure 4, S. Tucker, unpublished data). The population of primary nest predators in the region (skunk, fox, and raccoon [*Procyon lotor*]) increased 67%, 53%, and 79%, respectively, from 2010 to 2011.

In contrast to previous findings, cover type (i.e., native vs. introduced species) influenced daily survival rates of nests during the study (Klett et al. 1984, Arnold et al. 2007). Previous studies were conducted on fields using native plants that were dominant or co-dominant with introduced species, unlike my study fields which were composed exclusively of native plants. Native plantings in my study showed large discrepancies in nest success between years, however, having higher success than DNC in 2010 but much lower success in 2011.

The difference in nest success between the cover types in 2010 may have been due to the composition of species planted in the fields. Vegetation growth phenology differs between cover types, as vegetation in DNC typically begins active growth earlier in the nesting season than the warm-season species of native plantings which begin active growth later in the season. This phenology would lead to predictions that DNC would have higher success earlier in the season, while success would increase throughout the season in native fields as vegetation cover grew. I did not find support for this hypothesis, as nest success was similar between cover types early in the nesting season and decreased thereafter, with native plantings having lower success later in the nesting season than DNC. Other investigators have found similar results, with nest success decreasing significantly from the beginning to end of the nesting season (Flint and Grand 1996, Emery et al. 2005, Arnold et al. 2007). This decrease in success throughout the season may be due to predators responding to changing small mammal and insect populations (Pasitschniak-Arts and Messier 1998) or due to predators changing foraging patterns as the season progresses (Emery et al. 2005).

The sharp decrease in nest success in 2011 for native fields suggests current seed mixtures are more susceptible to temporal variability than DNC. Nest success also declined in DNC plantings, but not to the severity as native mixtures suggesting a relationship exists between nest success and cover type. Data from 2010 indicate in good years native plantings provide just as good, if not better, cover for nesting than DNC. Interestingly, there appears to be some factor(s) that affected native plantings in 2011 that DNC was robust to. Hens were apparently not able to identify this factor when selecting a nest site as they nested in similar densities in both cover types, despite poor nest success in native plantings. Native plantings appeared to only be affected late in the nesting season, as DSR was similar between cover types early in the nesting season, much like 2010. The factor limiting success may be due to vegetative characteristics within the field or could be a result of a difference in predator abundance and communities within the fields.

In 2011, native plantings did not provide the same vegetation characteristics as DNC. Litter depth was shallower and vegetation height was shorter than DNC during the late sampling period than. Cover density was also less dense in native plantings, though the difference was not statistically significant. The difference in litter depth was not likely important, as nest success was similar between cover types early in the nesting season in 2011. The standing residual warm-season grasses likely provided the same benefit as leaf litter in DNC, providing cover and concealment to early nesting species increasing nest success. Vegetation height and cover density were important covariates in explaining the variation in nest success (Chapter 2). The difference in cover could have led to a difference in the nest success between the cover types, as DSR decreased throughout the nesting season for this study. While nest success declined throughout the nesting season for both cover types, the effect was more pronounced in native fields (Figure 5). The difference in cover may have led to the more severe response for the native fields causing the significant decline in overall nest success between the cover types. This is likely not the only factor affecting success in native plantings; however, as the same pattern was seen in 2010 when vegetation characteristics were similar between cover types.

Alternatively, there may have been a difference in the predator abundance and/or community between the cover types. Although we did not measure predator abundance in our study, vegetative differences between cover types may have led to differences in predators. Native plantings provided more heterogeneity of habitats than DNC. This heterogeneity likely created more suitable habitats for alternative prey, especially small mammals (Bowman and

Harris 1980, Sietman et al. 1994, Nocera and Dawe 2008). If native plantings attracted more alternative prey, then it is possible the difference in small mammal abundance between the fields due to habitat heterogeneity may have led to a numerical response in predator densities (Holt 1977), resulting in increased predation of nests as generalist predators became more abundant (Voorhees and Cassel 1980, Norrdahl and Korpimäki 2000, Brook et al. 2008, Devries and Armstrong 2011). The decreased success in 2011 in native plantings may have been a result of poorer quality of cover that did not provide adequate concealment to remediate the effect of increased predator numbers responding to abundant alternative prey populations associated with native plantings.

The effectiveness of the native plantings was quite variable in this study, with the plantings providing similar vegetative structure 1 year resulting in higher success than DNC, while shorter vegetation and substantially lower success than DNC the next. In both years, nest success decreased dramatically as the season progressed. Understanding the mechanism that causes significantly lower success later in the nesting season than DNC is important if native plantings are to effectively replace DNC. Some of this variability may have come from the stage at which the stands are in, as native plantings are still in the establishment stage while DNC was in its stage of maximum growth (Table 1). The establishment stage for native plantings is usually associated with increased weeds and may not reflect the long term vegetation characteristics of the stand (Packard and Mutel 2005, Smith et al. 2010). During the establishment stage intensive management is required raising concerns on how this management effects duck production. While this intensive management may adversely affect nesting hens, its impact on duck production is likely less than that of DNC, where nesting cover is removed for 2-3 years. With large variability in the effectiveness of native fields for duck production, it is important that future research investigates the driving force behind the variability. Once this is identified, seed mixtures may be developed to remediate this variability and increase the effectiveness of native plantings for duck production.

CHAPTER 2

NEST-SITE SELECTION IN RESTORED NATIVE PRAIRIE AND DNC

INTRODUCTION

Habitat selection is the hierarchical process of behavioral responses that may result in disproportionate use of habitats to influence survival and fitness of individuals (Hutto 1985, Block and Brennan 1993). Selection of specific habitats is presumed to be an adaptive trait that increases individual fitness (Klopfer and Ganzhorn 1985). One of the most important aspects of habitat selection in birds is determining where to place a nest, as nest site selection likely influences predation rate and most annual mortality occurs during the breeding season (Ricklefs 1969). For ducks nesting in the PPR of the U.S., the vital rates that most influence individual fitness, thus sustain the population, are directly affected by nest-site selection; nest success and adult hen survival (Hoekman et al. 2002*b*). Selection of an appropriate nesting site should maximize both nest success and hen survival by providing protection from predators (Ost and Steele 2010) and controlling the microclimate (Gloutney and Clark 1997). Predators have been found to be the main cause of mortality to nests and hens during the breeding season (Ricklefs 1969) and have been identified as the driving force in the evolution of avian breeding biology (Ricklefs 1969, Martin 1993, Lima 2009). The impact of predation on individual fitness has likely created a trade-off between hen survival and nest survival, forcing hens to select nest sites that maximize nest survival, yet allow hens to escape predation themselves (Amat and Masero 2004). With increased predation, nest-site selection should be adaptive to select characteristics that maximize both nest and female survival (Ricklefs 1969).

Vegetation structure is often associated with the selection of safe nesting sites as nesting in dense cover protects from predators, wind, excess nocturnal radiation loss, or excess diurnal heat gain (Cody 1985). Nest-site characteristics are well documented for many species of waterfowl (Bellrose 1980) and are often found to be significantly different from random sites (Clark and Shutler 1999). This nonrandom distribution is assumed to be caused by habitat selection, and in order to be adaptive should increase fitness (Martin 1998, Clark and Shutler 1999). Vegetation characteristics can play a vital role in nest-site selection, as numerous studies have found vegetative characteristics affect the selection of nest-sites for birds (Duebbert and Lokemoen 1976, Livezey 1981*b*, Duebbert 1982, Hines and Mitchell 1983, Duncan 1986, Martin and Roper 1988, Crabtree et al. 1989, Clark and Shutler 1999, Durham and Afton 2003).

The role vegetation plays in nest-site selection is multi-faceted, with evidence supporting a hypothesized relationship between physical structure of vegetation and nest-site selection. Vegetation height, density, and litter depth are thought to influence selection decisions by providing concealment from nest predators, however, it may also be important for controlling the microclimate (Gloutney and Clark 1997, Hoekman et al. 2002*a*), restricting mammalian predator movements (Schrank 1972, Bowman and Harris 1980, Martin 1993), and limiting the foraging efficiency of predators by providing scent barriers (Duebbert 1969, Livezey 1981*a*). Understanding how these vegetation characteristics affect nest-site selection is important in making management decisions to maintain viable populations.

Vegetation height has been identified to be an important component of nest-site selection, with ducks appearing to select for taller vegetation (Livezey 1981*a*, Hines and Mitchell 1983, Bilogan 1992, Clark and Shutler 1999, Durham and Afton 2003). Selecting taller vegetation appears to be an adaptation that limits predation from visual predators, particularly avian (Dwernychuk and Boag 1972, Clark and Nudds 1991, Guyn and Clark 1997). While evidence suggests hens should select nest sites with the tallest vegetation, there may be a trade-off affecting the decision (Götmark et al. 1995). As vegetation height increases, the probability of detecting an approaching predator decreases, increasing the risk for the hen (Miller et al. 2007). Hines and Mitchell (1983) and Bilogan (1992) found support for this trade-off as they found nests to be located in intermediate cover. This intermediate cover likely allowed hens to be able to detect predators approaching the nest, yet still provided enough concealment of the nest to protect the eggs.

Another important physical structure of vegetation is the cover density. Cover density appears to be more important in limiting mammalian predation, as it restricts movement and limits scent dispersal around the nest (Duebbert 1969, Schrank 1972, Bowman and Harris 1980, Livezey 1981*a*, Hines and Mitchell 1983, Martin 1993). In general, studies have found hens select for more dense cover than random locations, with nest success increasing as cover density increases (Clark 1977, Livezey 1981*a*, Thornton 1982, Hines and Mitchell 1983, Clark and Shutler 1999). Support for adaptiveness of this trait under current environmental conditions is equivocal, however, with Clark et al. (1991) and Glover (1956) finding an inverse relationship with cover density and nest success. Much like vegetation height, there may be a trade-off in the selection of cover density. As density increases, the ability of a hen to detect and escape a predator decreases, resulting in a greater risk for the hen (Wiebe and Martin 1998, Miller et al. 2007). Conversely, as density decreases nests become more exposed, making them more vulnerable to predation (Dwernychuk and Boag 1972, Jones and Hungerford 1972). With no clear pattern prevailing, it is important to understand how vegetation cover affects nest-site selection when managing grassland habitat for ducks.

In addition to vegetation height and density, the amount of leaf litter (litter depth; mat of dead vegetation on the ground) may play an important role in nest-site selection. The overall importance of litter depth in selection of nest-sites has been documented for certain grassland songbirds (Swengel and Swengel 2001, Davis 2005, Fisher and Davis 2010), but the relative importance for ducks is largely unknown. Winter (1999) suggested that litter provides a suitable nesting substrate for ground-nesting ducks, as evidenced by all nest bowls being lined with litter. Litter may also provide concealment for early nesting species before green vegetation has grown up around the nest (Bue et al. 1952, Gjersing 1975, Clark 1977). This concealment likely helps reduce predation, with 1 study finding litter to be the most important cover component to nest success (Duebbert 1969). Identifying the importance of litter depth to nest-site selection for ducks will be a crucial step in determining the appropriate management for nesting habitat.

Previous research indicates physical structure of cover is more important than species composition of cover (Schrank 1972), however, hens may select nest-sites based on specific species of plant, while avoiding other species that may not provide safe nesting sites (Gilbert et al. 1996). While the physical structure of vegetation is determined by the composition of plants in that location, hens may prefer certain species of plants for reasons other than physical structure. For example, certain species of vegetation may be more effective at preventing the dispersal of odor or have other beneficial traits. Understanding these factors and identifying specific plant species that attract hens for nesting can guide future restoration efforts to maximize their effectiveness.

Waterfowl have adapted 2 strategies for nest distribution; colonial and dispersed nesting. Colonial nesting is nesting in close association of conspecifics allowing increased individual success by satiating predators after only a few eggs have been consumed or by group nest defense and vigilance against predators (Wittenberger and Hunt 1985, Richardson and Bolen 1999, Anderson and Titman 1992). The other strategy, dispersed nesting, increases nest survival by dispersing nests to a level that makes it too energetically inefficient for predators to search for nests (Lack 1968, Taylor 1976, Picman 1988). With habitat fragmentation, nest dispersal is limited to the available habitat and has potentially resulted in increased nest densities.

The effect of nest densities on nest success has been studied extensively, with no clear pattern emerging. Ackerman et al. (2004) found little evidence of density affecting nest success in real and artificial nests. Larivière and Messier (1998) found predation of artificial nests to be independent of density early in the nesting season, but density-dependent at extremely high densities late. Also, Duebbert and Lokemoen (1976) found no relationships between density and success of natural nests. In contrast, several studies found an inverse relationship between density and success of artificial nests (Sugden and Beyersbergen 1986, Larivière and Messier 1998, Gunnarsson and Elmberg 2008, Elmberg et al. 2009). Weller (1979) and Hill (1984) reported similar relationships in natural nests. Understanding the effect nest density has on nest survival can help guide management decisions pertaining to patch size characteristics.

A relatively accepted paradigm is large patches of habitat are better for production than isolated patches (Ball et al. 1995, Greenwood et al. 1995, Reynolds et al. 2001). Isolated patches potentially limit the ability of hens to space out, aggregating nesting hens and allowing predators to more easily forage for nests (Braun et al. 1978, Clark and Nudds 1991). Additionally, small isolated patches may concentrate predators, increasing the likelihood a predator encounters a nest (Clark and Nudds 1991). While managers focus on creating large extensive patches of nesting habitat, evidence of its effectiveness at increasing nest survival is variable (Clark and Nudds 1991). To maximize the efficiency of conservation dollars, it is important to understand how habitat should be protected, i.e. should managers focus on single large patches or small isolated patches?

While the attractiveness of taller vegetation, denser cover, and more litter to nesting ducks has been studied extensively, species specific preferences are less well understood and likely vary based on different life history traits. For instance, teal prefer nest-sites dominated by grasses with few forbs (Glover 1956, Livezey 1981*a*), while mallards and gadwall tend to select for more shrubs and forbs (Lokemoen et al. 1984). Identifying species specific preferences will be important for ensuring habitat management benefits the entire prairie nesting duck community rather than 1 or 2 species (Gilbert et al. 1996, McKinnon and Duncan 1999).

My objective was to determine if hens select specific vegetation characteristics for nest-sites and to identify species-specific factors that affected nest-site selection. I also analyzed how nest-site characteristics influenced nest success and identified factors effecting success of each species. I predicted hens are under stabilizing selective pressures with hens selecting intermediate vegetation characteristics, with nest success increasing with taller vegetation, denser cover, and deeper litter. Additionally, I predicted variation in vegetation characteristics and nest success among species with smaller species investing more into reproduction and having greater success than larger species.

METHODS

I analyzed the same nests as Chapter 1 to determine the vegetation characteristics that hens selected. At each nest-site, I determined the cover density, vegetation height, and litter depth (See Chapter 1). I compared these vegetation characteristics to non-nest site random locations in each field, using the same random locations as Chapter 1. Nests initiated on or before June 1 were compared to the first set of random location data while nests initiated after June 1 were compared to the last set of random location data. The cut-off date to determine early and late nests was selected based on personal observations of growth within the fields, selecting the approximate date when vegetation height increased dramatically over a short period of time. I used a MANOVA (PROC GLM; SAS 9.2 SAS Institute Inc., Cary, North Carolina, USA, 2008), with species or random location as the independent variable and vegetation height, cover density, litter depth, and size of grassland patch as the dependent variables, to compare the vegetation characteristics between nest-sites and random locations as well as differences between species (Gloutney and Clark 1997, Kolada et al. 2009). I compared the least squares means of vegetation height, cover density, litter depth, and size of grassland patch using the Tukey-Kramer adjustment for multiple comparisons to determine differences of vegetation characteristics between species. To determine if nest sites are under stabilizing selection, I determined the electivity index (Vanderploeg and Scavia 1979) for vegetation height and cover density. I assigned each nest and random location into a vegetation height and cover density class to the nearest 5 cm for the early and late sampling periods. In the early sampling period, I grouped all classes above 35 cm for vegetation height and 30 cm for cover density to avoid vulnerability to sampling errors for rare height and density classes in the environment (Lechowicz 1982). I grouped all height and density classes above 55 cm in the late sampling period. I used an ANCOVA (PROC GLM; SAS 9.2 SAS Institute Inc., Cary, North Carolina, USA, 2008) with density as the dependent variable and cover type, patch size, year, patch size*year interaction, and cover type*year interaction as the independent variables to determine the effect of patch size on nest site selection.

To determine the species composition of vegetation selected at each nest-site I used a meter-squared (m^2) area centered on each nest and random location. I identified each species of vegetation that occurred within the m^2 and assigned it a cover class (Table 11). To determine if hens selected specific vegetation for nesting compared to random locations and between species

I used an Analysis of Similarity (ANOSIM) in Decoda software (Minchin 1989), running 100 tests and 1,000 permutations. I graphed results using Ordination and Nonmetric Multidimensional Scaling (Shepard 1962, Kruskal 1964) in Decoda.

I used model building techniques to estimate the influence of covariates on nest survival. My global model included: cover type, year, the type*year interaction, date, age of nest when it was found, cover density at nest, quadratic term for cover density, height of vegetation at nest, quadratic term for height, litter depth, quadratic term for litter depth, size of habitat patch (area), density of nests in field, and the quadratic term for density of nests in the field. I included the quadratic term for cover density, vegetation height, litter depth, and density of nests to test for evidence of stabilizing selective pressure on nest site selection. I estimated the size of habitat patch as the amount of undisturbed grassland connected to the study field. I estimated the area using the measure tool in ArcGIS 9.3 (ESRI, Redlands, California, USA). To determine if variation in nest success between species was effected by body size (which is a strong correlate of annual survival), I used Linear Regression (PROC GLM; SAS 9.2 SAS Institute Inc., Cary, North Carolina, USA, 2008) and regressed nest success with the associated average body weight of hens (Ankney and Afton 1988, Lokemoen et al. 1990*b*, Mann and Sedinger 1993).

Preliminary analysis indicated nest success decreased with cover density in my study. I hypothesized this may be due to increased alternative prey density, especially in native vegetation. To test this hypothesis I compared a model that allowed the relationship between cover density and nest survival to differ between habitat types. I also included a model that allowed a relationship between vegetative density and nest survival for native vegetation only.

RESULTS

I analyzed data from 728 and 440 nests during the early and late sampling periods, respectively, in 2010 and 559 and 440 nests from the early and late periods respectively, in 2011. Nests were compared to 274 random locations in 2010 and 223 random locations in 2011. In both years, nest-site vegetation differed from random locations ($F_{1,27}$= 28.97, p <0.01; $F_{1,27}$ = 19.25, p <0.01; Table 12) for the early sampling period. In 2010, nests initiated in the late sampling period were different from random locations for all vegetative characteristics ($F_{1,27}$ = 11.33, p = 0.002), however, in 2011, nests initiated in the late sampling period were only different in vegetation height ($F_{1,27}$ = 22.13 p < 0.01) and cover density ($F_{1,27}$ = 18.19, p < 0.01) with no difference in litter depth ($F_{1,27}$ =1.51 p = 0.23; Table 13). Hens selected vegetation of intermediate height and cover density during the early sampling period, however, selected the tallest vegetation height and cover density in the late sampling period (Figures 6 and 7). There was no effect of patch size on nest density ($F_{1,27}$ = 1.33, p = 0.27; Figure 8).

Differences in nest-site vegetation characteristics existed between species during both sampling periods in both years (Tables 14-19). In general, mallards and gadwalls selected taller, denser vegetation than blue-winged teal, northern shovelers, and northern pintails. In only 1 sampling period, early 2010, was a difference in litter depth identified between species.

Results from ANOSIM tests indicated there was variation among species composition around nest-sites and random locations in fields. Despite finding multiple differences between species, the only consistent patterns identified was gadwall selected different vegetation than blue-winged teal and shovelers in 9 of 14 and 5 of 14 study fields, respectively, in 2011. These differences were driven by teal and shovelers selecting more grass species, while gadwalls selected more forbs. All other differences were identified in ≤ 3 fields. The other significant results were likely a result of random chance.

Model selection indicated that cover density, vegetation height, the quadratic term for vegetation height, litter depth, size of grassland patch, and the density of nests in a field explained the most variation in nest success data (Table 20). The next competing model included the top model with age of nest, however age of nest did not improve the deviance and the model was < 2 AICc points away, thus being an uninformative parameter (Arnold 2010). All other models were > 2 AICc points away from the top model, with the top model having a weight of 0.76.

The effect of vegetation characteristics on nest success influenced all of the species similarly (Table 21), with nest success: declining with increasing cover density (Figure 9), increasing with litter depth (Figure 10), and having a positive curvilinear relationship with vegetation height (Figure 11). Density of nests had a negative curvilinear relationship with success (Figure 12), except for northern shovelers (Figure 13) which had a linear inverse relationship. The size of grassland patch size also had an inverse relationship with success (Figure 14). Cover density affected nest survival differently between native and DNC plantings, with native plantings having lower success as cover density increased compared to DNC (Figure 15).

There were interactions between nest success covariates and species, with different covariates influencing nest success for species differently. The effect of body size on nest success was not significant ($F_{1,3} = 0.06$, $p = 0.83$). Nest success for northern pintail for the duration of the study was 43.89% (SE = 4.9) with the top model indicating success was influenced by cover density, vegetation height, and the quadratic term for vegetation height

(Table 22). Northern shoveler success was 46.22% (2.7) with the top model including litter depth and density of nests in a field (Table 23). Blue-winged teal success was 31.73% (2.6) and was best explained by the cover density, litter depth, area of grassland, density of nests, and the quadratic term for density of nests (Table 24). Gadwall success was 28.46% (3.2) while mallard success was 33.33% (4.2). Success was best explained for these species by vegetation height, density of nests, and the respective quadratic terms for these covariates (Tables 25 and 26).

DISCUSSION

Nest site characteristics differed from random locations as nest-sites had taller vegetation, greater cover density, and deeper litter, suggesting nest-site selection is under selective pressure (Southwood 1977). When attempting to determine if nest site selection is an adaptive trait, it is important to determine if hens are selecting for characteristics that increase fitness by comparing successful and unsuccessful nests (Clark and Shutler 1999). Model selection indicated nest success for all species combined was influenced by vegetation characteristics around nests as well as the size of grassland patch and the density of nests in the field (Table 21). My results suggest hens are selecting characteristics that increase nest success in regards to litter depth, and vegetation height, however, selection seems to be maladaptive in relation to density of cover and density of nests.

Vegetation Height

Evidence overwhelmingly supports vegetation height as an important characteristic in nest site selection, with hens selecting taller vegetation for nesting (Bue et al. 1952, Livezey 1981*a*, Hines and Mitchell 1983, Bilogan 1992, Clark and Shutler 1999, Durham and Afton 2003). Taller vegetation likely provides protection from visual predators, however, this selection does not appear to be directional, but rather stabilizing as evidence shows hens selecting intermediate heights of vegetation (Hines and Mitchell 1983, Bilogan 1992). Vegetation height appears to have a positive effect on nest success, with hens nesting in taller vegetation being more successful (Hines and Mitchell 1983, Crabtree et al. 1989, Bilogan 1992, Durham and Afton 2003).

My results corroborate previous work, as vegetation height at nest sites was significantly taller than random locations for all species. In agreement with Hines and Mitchell (1983) and Bilogan (1992), I found hens selected intermediate heights of vegetation rather than the tallest vegetation in the early sampling period. Previous studies have interpreted this selection as a tradeoff between nest success and hen survival with taller vegetation leading to higher nest survival at the cost of hen survival (Götmark et al. 1995). My results, however, suggest this tradeoff does not need to occur for hens to select intermediate heights of vegetation. I found nest survival to be curvilinear indicating the relationship between nest success and vegetation height is under stabilizing selective pressures. The decrease in success as vegetation height increases may be due to a shading effect on understory vegetation. As vegetation height increases light penetration to understory vegetation is restricted resulting in sparse cover near the ground, potentially increasing the risk of predation by mammalian predators (Crabtree et al. 1989). Hens selecting taller vegetation may be exposed to increased predation due to the shading effect that occurred around nest-sites, causing success to decline as vegetation height increased. During the late sampling period, hens selected the tallest vegetation available. The differential selection of height between early and late season may be due to a difference in the species nesting later in the season. Gadwalls were the most common nesting species late in the season, accounting for ~ 50% of all nests found.

Cover Density

Similar to taller vegetation, greater vegetation density has been hypothesized to provide high quality nest sites in waterfowl (Duebbert 1969, Schrank 1972, Hines and Mitchell 1983, Crabtree et al. 1989). In accordance with this hypothesis, hens typically select denser vegetation for nest sites than random locations (Deubbert 1969, Schrank 1972, Livezey 1981*a*, Clark and Shutler 1999). Selection of denser cover alone does not constitute high quality nest sites, the cover selected must afford reproductive benefits in increased clutch survival (Van Horne 1983). Denser vegetation provides barriers to predators (Schrank 1972, Bowman and Harris 1980, Hines and Mitchell 1983) limiting their foraging efficiency for nests, presumably resulting in higher nest survival (Clark 1977, Livezey 1981*a*, Thornton 1982, Clark and Shutler 1999), however, evidence supporting this hypothesized relationship has been ambiguous (Glover 1956, Clark et al. 1991).

Like previous findings, hens in this study selected nest sites with greater cover density than random locations. Furthermore, consistent with previous studies, hens appeared to select intermediate cover density in the early sampling period, suggesting it is under stabilizing selection (Livezey 1981*a*, Hines and Mitchell 1983, Clark and Shutler 1999, Durham and Afton 2003). This selection of intermediate density has been interpreted as a tradeoff between nest and hen survival with greater density and concealment benefitting the eggs at the cost of hen survival (Wiebe and Martin 1998, Amat and Masero 2004, Miller et al. 2007). Like vegetation height, hens selected the densest cover late in the nesting season, presumably due to differences in the species nesting between the time periods.

In contrast to my prediction and previous findings, I found nest success to decline as cover density increased. This may be a result from the unique habitat types used in my study.

Previous research indicates diverse native vegetation supports a more diverse and potentially abundant community of fauna (Bowles and Copsey 1992, Sammon and Wilkins 2005, Bakker and Higgins 2009, Isaacs et al. 2009, Litt and Steidl 2011). Because predators prey on duck nests opportunistically (Vickery et al. 1992), an increased abundance of alternative prey may have increased nest predation due to a numerical response in predators, resulting in an increased likelihood a predator will encounter a nest. Thus, the negative relationship between vegetation density and nest success in my study may be due to a positive relationship between native vegetation density and alternative prey, thus predator density. This interpretation is supported by my analysis indicating lower nest success in native plantings as cover density increased compared to DNC (Figure 15).

My results suggest that hens are currently making maladaptive decisions in relation to cover density when selecting a nest-site. This may be due to characteristics of successful nests varying over time and space (Austin 1976, van Riper 1984). Alternatively, nesting habitat loss due to agricultural development causing artificial increases in densities and increased abundance of meso-predators due to the loss of top predators has led to a long term decline in nest success. These recent changes in habitat availability and predator density due to human influence may be occurring at a greater rate than nesting hens can adapt, causing hens to make maladaptive decisions. Despite apparent maladaptive decisions, nest success was quite high during this study (Chapter 1). The selective pressures in this study may reflect long term adaptive decisions that are neutral or maladaptive in the short time the study was conducted or an inability for ducks to adapt relative to the rate of recent anthropogenic changes to the environment (Clark and Shutler 1999).

Litter Depth

Vegetation litter is used by ducks as a nesting substrate, yet the influence of litter depth on nest-site selection has been relatively unexplored (Fisher and Davis 2010). Burgess et al. (1965) and Glover (1956) surmised that blue-winged teal did not nest in recently managed fields due to a lack of litter. Lokemoen et al. (1984) suggested litter depth did not affect nest site selection but previous work has hypothesized that litter depth is important for nest success (Duebbert 1969), likely providing concealment and controlling the microclimate of the nest (Bue et al. 1952, Gjersing 1975, Clark 1977).

During this study, nest sites had significantly deeper litter than random locations early in the nesting season, indicating litter depth is a selected characteristic. Selection patterns late in the nesting season were variable, with nest sites having significantly deeper litter in 2010, but not in 2011. Litter depth likely becomes less important in concealment and controlling the microclimate later in the season as new vegetation can provide these benefits, reducing its importance and decreasing selective pressure for deeper litter.

The importance of litter depth to duck nesting success has been hypothesized in previous work (Glover 1956, Keith 1961, Duebbert 1969, Gjersing 1975), however, few studies have been able to quantify the actual importance litter plays for nesting hens. My findings indicate litter depth is positively correlated with nest success suggesting management for litter depth within fields should be a priority for managers. Litter depth may benefit nests in a variety of ways, most likely helping to control the microclimate of the nest (Gloutney and Clark 1997) or increasing concealment for early nesting species (Duebbert 1969). Creating management plans to account for litter depth may be complex. While these findings suggest managers should focus on increasing litter depth in grasslands, previous work has found litter accumulation causes a decline of stand vigor (Xiong and Nilsson 1999, Naugle et al. 2000, Devries and Armstrong 2011). Future research and management should focus on finding a management plan that can provide adequate litter for nesting hens while limiting its effect on vegetation (Naugle et al. 2000).

Patch Size

Since the NAWMP was established, managers have focused on restoring large blocks of grassland habitat to increase nest success as expansive areas of upland cover were thought to be beneficial (Ball et al. 1995, Greenwood et al. 1995, Reynolds et al. 2001). Hence, larger blocks of habitat are better than smaller isolated patches (Clark and Nudds 1991, Kantrud 1993, Sovada et al. 2000), and increased amounts of grassland on the landscape should be more attractive to ducks than landscapes dominated by agriculture (Greenwood et al. 1995, Reynolds et al. 2001). Arnold et al. (2007) found the opposite effect of perennial cover, as nest density decreased with increased amounts of perennial cover in the landscape. The effect of patch size on nest success has long been debated with mixed results (Clark and Nudds 1991).

I did not find an effect of patch size on nest site selection or nest success for all species combined, however, teal nest survival was inversely related to patch size (Table 23). In cropland dominated landscapes like the area of this study, larger grassland patches likely attract predators, increasing the predation risk to hens (Phillips et al. 2003). Anthropogenic changes to the PPR likely benefited many predator species, however, monotypic stands of grain crops are also detrimental to predators making perennial cover attractive (Sargeant et al. 1993, Gehring and Swihart 2003). These findings suggest that management plans to create large expanses of upland cover may not benefit nesting hens, and instead should focus on creating smaller patches that predators may avoid due to insufficient prey items.

Nest Density

Waterfowl have evolved 2 main nest distribution strategies; colonial and dispersed nesting. Colonial nesting is seen in arctic nesting geese, likely as a result of an increased ability to defend nests against predators (Anderson and Titman 1992). Colonial nesting can increase reproductive success by swamping predators, improving nest defense, and increased vigilance (Burger 1984, Wittenberger and Hunt 1985, Richardson and Bolen 1999). For species that are unable to defend their nests against predators, like dabbling ducks in the PPR, the best defense is to increase concealment and disperse their nests to a level that is not energetically efficient for predators to search for nests (Lack 1968, Taylor 1976, Picman 1988).

Creating smaller patches of habitat for nesting may increase nest densities as hens have a limited amount of space to disperse nests. The effect of nest density on nest success for dispersal nesters like upland-nesting ducks has been variable (Duebbert and Lokemoen 1976, Weller 1979, Hill 1984, Ackerman et al. 2004). Nest densities in my study affected nest survival with a negative curvilinear relationship (Figure 12). This suggests density-dependent predation is occurring at lower densities, but may be overcome as predators become satiated (Larivière and Messier 1998). Nams (1997) found striped skunks became satiated after eating 6-7 eggs, which is less than the average clutch size. Therefore, it appears when densities reach high levels, predators become satiated and as a result nest survival increases.

Species-Specific Variation in Nest Site Characteristics

My findings are consistent with previous research indicating preference for specific vegetation characteristics at nest sites varies among duck species (Duncan 1986, Greenwood et al. 1995, Clark and Shutler 1999). The general patterns of variation in my study follow previous trends found by other authors with mallards and gadwalls selecting the tallest, densest vegetation while teal, shovelers, and pintails selected intermediate heights and densities during the early sampling period (Keith 1961, Bilogan 1992, Hines and Mitchell 1983, Lokemoen et al. 1990*a*). Species-specific selection patterns for litter depth were variable during the early sampling period with gadwall and teal selecting deeper litter compared to other species; however this relationship only existed in 2010. Gadwall and teal typically initiate nesting later in the season when new vegetation growth has emerged, unlike mallards and pintails (Krapu 2000). In 2010, temperatures warmed up rapidly allowing later nesting species to initiate nesting earlier in the season before vegetation growth occurred (Drever and Clark 2007). This swift temperature increase caused rapid snow melt, increasing surface flows of water. This left little standing residual vegetation and increased litter depths as the runoff knocked down vegetation. It is possible the increased litter depths were more important in concealing nests of teal and gadwall during this sampling period when standing vegetation was sparse, driving interspecific variation in litter depths to accommodate for the lack of vegetation usually abundant when these species begin nesting.

During the late sampling period, patterns in variation were similar with the exception of pintails selecting vegetation characteristics similar to mallards and gadwalls. This selection is quite intriguing as pintails are known to nest is sparse cover (Kalmbach 1938, Keith 1961), yet consistently selected vegetation characteristics similar to mallards and gadwalls late in the nesting season. Pintails typically initiate nests early in the nesting season before new vegetation growth has started (Bellrose 1980, Duncan 1987*a*, Greenwood et al. 1995, Guyn and Clark 2000). The nests found late in the nesting season may have been re-nesting attempts from hens that have already lost their nest (Grand and Flint 1996, Richkus 2002). Previous encounters with predators may have led hens to select taller and denser cover due to a learned behavior from previous failed nesting attempts in sparse cover (Marzluff 1988).

Vegetation Species vs. Structure

My findings support the hypothesis that hens look more for vegetation structure than specific species of vegetation (Schrank 1972, Crabtree et al. 1989). The only differences I found in selection of specific species of plants was gadwall selecting more forbs and less grass than teal and shovelers, however, this relationship did not exist in all fields. Differences in species composition has been identified between these species in previous work, with results suggesting teal and shovelers select more grasses and avoided forbs while gadwalls selected for more forbs and shrubs (Kaiser et al. 1979; Weller 1979; Livezey 1981*a*; Hines and Mitchell 1983; Klett et al. 1984, 1988; Crabtree et al. 1989). The species composition selected likely represented the respective vegetative structure each species prefers, with gadwall selecting taller and denser vegetation than teal and shovelers. There were 54 other significant results found, however, the relationships only existed in a couple of fields for each comparison. These results may have been a result of random chance, as I ran 100 tests in each field, 2,800 total between both years, which at an alpha level of 0.05 would produce 140 significant differences based on chance alone.

The selection of various vegetation characteristics by different species exemplifies the importance of diverse habitats to support the entire guild of upland-nesting ducks (Gilbert et al. 1996, McKinnon and Duncan 1999). Creating a diverse habitat that supports this guild is a challenge with increasing losses of grasslands in the region (Stephens et al. 2008). Creating habitats that have tall, dense cover as well as intermediate height and density will be important for the continued conservation of upland-nesting ducks.

Species-Specific Variation in Nest Success

The effect of vegetation characteristics on nest survival varied among species. This variation appeared to be related to preferred nest site characteristics, as mallards, gadwall, and pintail selected the tallest vegetation and vegetation height was an important covariate explaining the variation in nest survival for these species. Teal and shovelers, which nested in shorter, less dense vegetation, were more influenced by litter depth. These results indicate individuals have adapted to select nest sites that best suit their species specific requirements. Despite these relationships, however, nest survival varied greatly between species nesting in similar vegetation characteristics. For instance, gadwall had lower success than mallards, even though the top model explaining variation in nest survival was identical between the species. Based on the model selection results for each species, it appears that influences other than vegetation had an effect on these results. Life history characteristics may explain variations in nest survival among species. Possible life history characteristics that may have affected individual success include varying reproductive investment based on body size, average nest initiation date, and the distance a species nests from water. Previous studies have found variations for these 3 characteristics among species (Keith 1961, Zammuto 1986, Duncan 1987*a*).

One characteristic other than vegetation that may influence nest survival is reproductive investment. The level of reproductive investment should be reflected by its annual mortality, with species with lower annual mortality investing less in their current reproductive effort (Stearns 1977). Body size is a good predictor of annual mortality between closely related species like ducks, with larger-bodied species like mallards and pintails having lower mortality than smaller-bodied species like teal and shovelers (Bellrose 1980). Higher mortality should result in life history traits that favor current reproduction over future attempts. This is evidenced by larger clutch sizes in smaller species like teal and shovelers (Zammuto 1986). Increasing the number of eggs laid in a clutch increases the investment of the current reproductive attempt while likely decreasing an individual's survival (Hanssen et al. 2005). Nest defense offers another example of increased investment in smaller-bodied species as demonstrated by the negative relationship between body size and vigor of nest defense (Forbes et al. 1994, Dassow et al. 2012). The increased investment in current reproductive attempts should result in higher nest success for smaller-bodied species. My results do not show support for this hypothesis, as regression analysis did not find a relationship between body size and nest success.

An alternative hypothesis to the variation in nest success among species is nesting chronology. Nest success was highest earlier in the season and decreased thereafter, suggesting earlier initiating hens should have higher success than later initiating hens. Pintails typically initiate nesting earlier than the other species (Bellrose 1980, Duncan 1987*a*, Greenwood et al. 1995, Guyn and Clark 2000) and had higher success than most late nesting species, however, mallards also nest early in the season and had much lower success than pintails. Mallards are known to be more prolific re-nesters than pintails (Duncan 1987*a*, Richkus 2002, McPherson et al. 2003), resulting in more mallard nests later in the nesting season than pintails, when nest success was lowest. Additionally, gadwall and teal, known to be the latest nesting species (Drever and Clark 2007), had the lowest success providing more evidence that initiation date may be important in explaining variation among species. Nest success may have been lower later in the nesting season due to density-dependent predation. Nest density had a negative effect on survival in this study, thus, it is possible that due to their early nesting habits pintails avoided the effect of density-dependent predation, while later nesting species were affected. Alternatively, increased alternative prey populations later in the nesting season (Crabtree and Wolfe 1988) may have attracted predators increasing incidental encounters with nests, thus decreasing success.

The last hypothesis explaining variation in species nest success is the distance a hen nested from water. I did not measure the distance a hen nested from water, however, nest success patterns among species suggests it may have played an important role in determining nest survival. Variation in the distance various species nest to water has been found in previous work, with species nesting in close proximity to water being more vulnerable to predation as predators use wetland edges more frequently than interior habitat (Duebbert and Lokemoen 1976, Livezey 1981*b*, Crabtree et al. 1989, Larivière and Messier 2000, Phillips et al. 2003). Teal and gadwall had the lowest nest survival in my study and previous findings have found these species to nest closer to water than other closely related species (Livezey 1981*b*, Crabtree et al. 1989). Pintails, on the other hand, tend to nest further from water (Keith 1961, Duncan 1987*b*), and subsequently had the highest nest survival in my study. There may be a tradeoff between nest survival and duckling survival, where nest survival is lower closer to water, but duckling survival is higher as overland movements, which may reduce duckling survival (Sayler 1962, Ball et al. 1975), are shorter. Thus, if teal ducklings suffer greater mortality during overland movements it would be advantageous for hens to nest closer to water, despite low nest success, to increase productivity. Previous evidence has shown that pintail ducklings are able to withstand long overland movements without a reduction in body condition (Duncan 1987*b*), suggesting pintails have adapted to nest farther from water where predation is lower (Page and Cassel 1971, Livezey 1981*b*). This hypothesized tradeoff may account for the variation in species nest survival in my study.

My results suggest vegetation characteristics alone do not account for all variation in nest survival and interactions between life history traits likely play a key role. Future research should address the variation in nest survival among species to gain a better understanding of the factors affecting individual species, allowing management plans to benefit all species.

CONCLUSIONS

Nesting habitat continues to be lost at a detrimental pace in the PPR jeopardizing future duck production (Stephens et al. 2008). Efficiently managing the remaining habitat to maximize duck production is important to conserve both habitat and financial resources. Dense nesting cover provides attractive nesting habitat for nesting hens, however, the effectiveness of increasing production has been variable (McKinnon and Duncan 1999). The cyclic management of DNC is expensive (Lokemoen 1984), thus provoking managers to replace DNC with native species. Early attempts of restoring native plantings were unsuccessful, with nest densities and success lower than DNC (Kaiser et al. 1979, Rodriguez 1984). This was likely due to a lack of diversity in the plantings that allowed them to be easily invaded by non-native species that did not provide sufficient vegetation structure for nesting. More diverse native plantings, however, should provide excellent nesting habitat for ducks as they have adapted to nest in similar vegetation prior to anthropogenic changes, and may be more resistant to invasion than previous mixtures.

I found nest densities to be similar between cover types, suggesting native plantings provide the same nesting opportunity as DNC. Nest success in native plantings, however, was extremely variable between years, unlike DNC which was relatively stable. Nesting success was similar early in the nesting season, however, native plantings seeded with current seed mixtures at current stages of establishment produced lower nest success late in the nesting season. With success being similar early in the nesting season, it is likely that the decreased nest success later in the season has little effect on population dynamics of earlier nesting ducks, as earlier hatched duckling are more likely to be recruited into the fall flight than later hatching ducklings (Dzus and Clark 1998, Dawson and Clark 2000). Nonetheless, the lower success later in the nesting season is reason for concern over the effectiveness of native plantings at this stage using current seed mixes.

Differences in nest success between cover types may have been due to the cover types being in different stages of growth. While stand ages were similar between cover types in this study, native plantings were still in the establishment stage, which often results in increased weeds and may not reflect the intended long-term cover characteristics (Shirley 1994). Conversely, DNC stands, which are designed to establish readily and quickly, were in the stage of their most vigorous growth, likely maximizing the benefits to duck production for this cover type. Nonetheless, future research is needed to determine the cause of variation in nest success of native plantings and try to develop management regimes and seed mixtures to remediate this variation and increase the effectiveness for native plantings to be justified. One possible remedy would be to include more cool-season species in the mixes. These species would increase vegetation growth earlier in the year, especially in years when temperatures are cooler in spring, providing better cover late in the nesting season.

Vegetation characteristics influenced nest success in my study. These characteristics may have interacted with the cover types to cause the lower success in native plantings in 2011. Previous studies have shown nest success to increase as cover density increases (Hines and Mitchell 1983, Clark and Shutler 1999). In my study, however, increased cover density negatively affected nest success in both cover types, however, native plantings were affected more than DNC. This relationship occurred despite vegetation being shorter and less dense than DNC in the late sampling period of 2011. Although more dense vegetation may restrict the movement of duck and nest odor, as well as predators, populations of small mammals increase with cover density and are more abundant in native plantings than introduced cover types

(Bowles and Copsey 1992 Sietmann et al. 1994, Nocera and Dawe 2008). In general, increased numbers of small mammals likely attracted predators to areas with dense vegetation, causing success to decline with cover density. In native plantings, the positive association between alternative prey and native plantings may attract a greater abundance of small mammals at lower cover densities than DNC, leading to an increase in predators without the added benefit of protection from predators commonly found in denser vegetative cover. With less dense vegetation, foraging efficiency for nests was likely greater in native plantings, causing the decline in success. Thus, current native seed mixtures used in this study did not provide the same benefits to duck production as DNC in each year. Native plantings appear to be successful at increasing faunal diversity but the negative effects on duck production needs to be remediated by creating native seed mixtures that alleviates variation in vegetation characteristics and nest success between years.

To increase stand vigor and health, management practices are necessary, however, little information is known on the best management practices to increase stand health (Naugle et al. 2000). Currently, managers use a combination of mowing, grazing, and fire. The effect of these management practices on duck production is not well understood. Devries and Armstrong (2011) found nest success to be higher the year after management and decline afterwards, while nest density was lowest the year after management and increased thereafter. I did not have enough data to address this issue, but the limited amount I collected suggested similar findings. There is a great need for future research to address the impacts of management on production, as well as the best management approaches to increase stand vigor.

Variation occurred in nest site characteristics and success among species, with species selecting different heights and densities of vegetation for nesting. These differences did not appear to affect the variation in nest success, however, as species that selected similar characteristics had dissimilar nest survival rates suggesting life history characteristics play an important role in explaining nest success. Body size, a surrogate for annual survival, did not appear to effect nest success. Other possible explanations are differences in reproductive investment between species, variation in nest initiation date among species, and the distance a hen nests from water. More information is needed to understand how life history traits interact with habitat selection, as this information can prove useful when developing management plans. Understanding factors effecting nest success and duckling survival in each species will allow managers to create habitats that effectively protect hens and their nests from predators.

Table 1. List of study sites including Waterfowl Production Area (WPA), field name, type of cover, size of field, age of stand (years since field was seeded as of 2010), and cluster.

WPA / NWR*	Field Name	Cover	Hectares	Age of Stand	Cluster
Nikolaisen	Central	DNC	43	6	3
Nikolaisen	Register West	Native	40	4	3
Nikolaisen	Cami	Native	32	5	3
Nikolaisen	South	DNC	13	6	3
Nikolaisen	Southeast	DNC	59	18	3
Halvorson	Native	Native	61	16	3
Lake Alice	DNC	DNC	64	6	1
Lake Alice	Toilet	Native	22	2	1
Lake Alice	North	DNC	8	6	1
Martinson	West	DNC	41	2	2
Martinson	DNC	DNC	28	7	2
Phil Aus	Northwest	DNC	38	6	2
Dahl	Native	Native	26	15	2
Weaver	DNC	DNC	26	21	2

* Waterfowl Production Area/ National Wildlife Refuge

Table 2. Average vegetation height (SE), cover density, litter depth, and mixed model ANOVA results for random locations in multi-species native plantings and dense nesting cover (DNC) during the early and late sampling period in 2010 in the Devils Lake Wetland Management District, North Dakota.

	Early Sampling Period				Late Sampling Period			
Vegetation Characteristic	DNC	Native	F Value	*P* Value	DNC	Native	F Value	*P* Value
Height (cm)	11.94 (1.38)	10.73 (2.20)	0.22	0.65	28.04 (2.12)	23.82 (2.32)	2.50	0.15
Cover Density (cm)	6.51 (0.89)	4.22 (0.57)	4.63	0.06	19.59 (2.92)	15.84 (1.86)	1.17	0.30
Litter (cm)	4.56 (0.54)	3.24 (0.51)	3.31	0.10	-	-	-	-

Table 3. Average vegetation height (SE), cover density, litter depth, and mixed model ANOVA results for random locations in multi-species native plantings and dense nesting cover (DNC) during the early and late sampling period in 2011 in the Devils Lake Wetland Management District, North Dakota.

	Early Sampling Period				Late Sampling Period			
Vegetation Characteristic	DNC	Native	F Value	*P* Value	DNC	Native	F Value	*P* Value
Height (cm)	10.22 (1.61)	8.94 (0.85)	0.03	0.87	33.65 (2.97)	19.35 (2.69)	35.3	< 0.01
Cover Density (cm)	8.40 (1.66)	5.99 (0.76)	0.82	0.41	23.63 (4.41)	13.01 (2.68)	4.15	0.10
Litter (cm)	5.00 (0.63)	2.44 (0.37)	8.33	0.03	-	-	-	-

Table 4. Total number of nests broken down by cover type and species in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Cover Type	Year	Mallard	BWT[1]	Gadwall	Shoveler[2]	Pintail[3]	GWT[4]	Scaup[5]	Wigeon[6]	Total
Native	2010	98	212	254	138	61	7	21	7	798
Native	2011	102	162	125	66	43	5	8	4	515
DNC	2010	126	315	346	234	96	5	65	4	1,191
DNC	2011	191	274	317	115	85	0	36	2	1,020
Total		517	963	1042	553	285	17	130	17	3,524

1 = Blue-winged Teal
2 = Northern Shoveler
3 = Northern Pintail
4 = Green-winged Teal
5 = Lesser Scaup
6 = American Wigeon

Table 5. Nest densities for each field in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Field	Cover Type	Field Age	Year	Nest Density (nests/ha)
Toilet	Native	6	2010	15.06
			2011	Managed
Lake Alice DNC	DNC	4	2010	11.46
			2011	12.05
Lake Alice North	Native	5	2010	12.85
			2011	Managed
Martinson Native	Native	6	2010	4.49
			2011	10.18
Martinson DNC	DNC	18	2010	5.94
			2011	10.10
Phil Aus	DNC	16	2010	6.41
			2011	5.59
Dahl	Native	6	2010	3.40
			2011	8.41
Weaver	DNC	2	2010	7.62
			2011	8.58
Register West	Native	6	2010	1.77
			2011	Managed
Cami	Native	2	2010	3.43
			2011	Managed
Nikolaisen Central	DNC	7	2010	2.40
			2011	Managed
Nikolaisen South	DNC	6	2010	4.57
			2011	Managed
Nikolaisen Southeast	DNC	15	2010	2.71
			2011	3.10
Halvorson	Native	21	2010	1.09
			2011	1.19

Table 6. Nest density (SE) and mixed model ANOVA results examining effect of cover type on density in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Year	Cover Type	Density (nests/ha)	F Value	Prob > F
2010	Native	6.01 (2.11)	0.48	0.51
	DNC	5.87 (1.18)		
2011	Native	6.59 (2.75)	0.08	0.79
	DNC	7.88 (1.60)		

Table 7. Number of nests per hectare (SE) of each species nesting in multi-species native plantings and dense nesting cover (DNC) in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Year	Cover Type	Mallard	Gadwall	Pintail[1]	BWT[2]	Shoveler[3]
2010	Native	0.77 (0.29)	1.57 (0.76)	0.42 (0.08)	1.63 (0.62)	0.84 (0.16)
	DNC	0.75 (0.16)	1.76 (0.38)	0.49 (0.11)	1.53 (0.43)	1.13 (0.12)
2011	Native	1.19 (0.98)	1.72 (0.99)	0.50 (0.19)	2.06 (0.67)	0.65 (0.18)
	DNC	1.34 (0.54)	2.34 (0.90)	0.71 (0.39)	2.92 (0.67)	0.90 (0.16)

1 = Northern Pintail
2 = Blue-winged Teal
3 = Northern Shoveler

Table 8. Nest success and associated standard error for each field in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Field	Cover Type	Year	Nest Success (%)	Standard Error
Toilet	Native	2010	36.80	4.3
		2011	Managed	-
Lake Alice DNC	DNC	2010	15.06	2.8
		2011	38.77	5.8
Lake Alice North	Native	2010	16.20	4.8
		2011	Managed	-
Martinson Native	Native	2010	59.68	5.2
		2011	14.10	2.0
Martinson DNC	DNC	2010	73.92	4.9
		2011	32.28	4.1
Phil Aus	DNC	2010	12.78	3.1
		2011	30.68	4.0
Dahl	Native	2010	71.34	6.4
		2011	3.15	1.6
Weaver	DNC	2010	67.56	4.9
		2011	50.87	4.5
Register West	Native	2010	40.46	8.4
		2011	Managed	-
Cami	Native	2010	59.20	6.3
		2011	Managed	-
Nikolaisen Central	DNC	2010	63.00	6.7
		2011	Managed	-
Nikolaisen South	DNC	2010	33.04	8.2
		2011	Managed	-
Nikolaisen Southeast	DNC	2010	54.88	5.7
		2011	25.87	4.8
Halvorson	Native	2010	60.25	8.5
		2011	44.49	10.4

Table 9. Model selection results, including number of parameters (K) and model weight (w_i), used to examine the effect of cover type on nest success in multi-species native plantings and dense nesting cover in 2010-11 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	W_i	K	Deviance
Cover Type	6,902.30	0.00	1.00	2	6,898.30
Null	6,917.01	14.71	0.00	1	6,915.01

Table 10. Model selection results, including number of parameters (K) and model weight (w_i), used to examine the effect of nest initiation date on nest success in multi-species native plantings and dense nesting cover in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	W_i	K	Deviance
Type*Initiation	3,794.95	0.00	0.95	4	3,786.95
Type + Initiation	3,800.65	5.70	0.05	3	3,794.65
Cover Type	3,821.94	26.99	0.00	2	3,817.94
Null	3,905.58	110.63	0.00	1	3,903.58

Table 11. Canopy cover classes used to determine species composition at nest sites and random locations using the 1-m^2 quadrat in the Devils Lake Wetland Management District, North Dakota.

Class	Range (% cover)	Midpoint
1	0-5	2.5
2	5-25	15.0
3	25-50	37.5
4	50-75	62.5
5	75-95	85.0
6	95-100	97.5

Table 12. Average vegetation height, cover density (visual obstruction), and litter depth (SE) at nest sites of all species combined and random locations during the early sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

	2010		2011	
Variable	Nest-Site	Random	Nest-Site	Random
Height (cm)	23.26 (1.82)	11.34 (1.26)	15.56 (1.18)	8.12 (0.89)
Cover Density (cm)	14.49 (2.18)	5.36 (0.60)	12.40 (1.25)	5.46 (0.97)
Litter (cm)	6.75 (0.46)	3.90 (0.40)	5.55 (0.40)	3.17 (0.35)

Table 13. Average vegetation height, cover density (visual obstruction), and litter depth (SE) at nest sites of all species combined and random locations during the late sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

	2010		2011	
Variable	Nest-Site	Random	Nest-Site	Random
Height (cm)	40.84 (2.42)	25.93 (1.62)	41.24 (2.68)	23.55 (2.64)
Cover Density (cm)	33.63 (2.71)	17.71 (1.74)	31.38 (2.32)	16.27 (2.68)
Litter (cm)	5.97 (0.47)	3.90 (0.40)	3.78* (0.36)	3.17* (0.35)

* Non-significant difference

Table 14. Average vegetation height (SE) at nest sites of the 5 most common nesting species and random locations during the early sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota. Species with the same Tukey-Kramer Comparison letter are not different.

	2010		2011	
Species	Height (cm)	Tukey-Kramer Comparison	Height (cm)	Tukey-Kramer Comparison
Mallard	25.05 (1.36)	A	21.18 (0.74)	A
Gadwall	25.91 (1.08)	A	23.75 (2.47)	A
Pintail[1]	21.05 (1.69)	AB	15.80 (1.05)	B
Shoveler[2]	21.88 (0.50)	AB	15.69 (0.61)	B
BWT[3]	21.38 (0.81)	B	17.50 (0.56)	B
Random	11.59 (0.88)	C	8.41 (0.39)	C

[1] Northern Pintail
[2] Northern Shoveler
[3] Blue-winged Teal

Table 15. Average vegetation height (SE) at nest sites of the 5 most common nesting species and random locations during the late sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota. Species with the same Tukey-Kramer Comparison letter are not different.

	2010		2011	
Species	Height (cm)	Tukey-Kramer Comparison	Height (cm)	Tukey-Kramer Comparison
Gadwall	49.90 (1.06)	A	47.11 (0.93)	A
Pintail[1]	48.53 (4.08)	AB	45.42 (3.10)	AB
Shoveler[2]	42.13 (2.47)	B	40.51 (2.39)	BC
BWT[3]	41.83 (1.61)	B	33.53 (1.04)	C
Random	25.31 (0.55)	C	24.64 (0.80)	D

[1] Northern Pintail
[2] Northern Shoveler
[3] Blue-winged Teal

Table 16. Average cover density (SE) at nest sites of the 5 most common nesting species and random locations during the early sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota. Species with the same Tukey-Kramer Comparison letter are not different.

	2010		2011	
Species	Cover Density (cm)	Tukey-Kramer Comparison	Cover Density (cm)	Tukey-Kramer Comparison
Mallard	13.25 (0.78)	B	18.16 (0.72)	A
Gadwall	19.07 (0.84)	A	19.58 (2.02)	A
Pintail[1]	9.25 (0.55)	C	13.57 (0.86)	B
Shoveler[2]	12.38 (0.36)	B	12.82 (0.46)	B
BWT[3]	12.95 (0.42)	B	13.57 (0.35)	B
Random	5.31 (0.35)	D	5.98 (0.32)	C

[1] Northern Pintail
[2] Northern Shoveler
[3] Blue-winged Teal

Table 17. Average cover density (SE) at nest sites of the 5 most common nesting species and random locations during the late sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota. Species with the same Tukey-Kramer Comparison letter are not different.

	2010		2011	
Species	Cover Density (cm)	Tukey-Kramer Comparison	Cover Density (cm)	Tukey-Kramer Comparison
Mallard	40.91 (1.95)	AB	42.94 (1.69)	A
Gadwall	40.56 (0.97)	A	39.59 (0.97)	A
Pintail[1]	38.38 (3.67)	AB	37.35 (3.12)	AB
Shoveler[2]	32.88 (1.85)	B	33.08 (2.58)	BC
BWT[3]	34.33 (1.29)	B	25.87 (0.94)	C
Random	17.16 (0.57)	C	16.36 (0.82)	D

[1] Northern Pintail
[2] Northern Shoveler
[3] Blue-winged Teal

Table 18. Average litter depth (SE) at nest sites of the 5 most common nesting species and random locations during the early sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota. Species with the same Tukey-Kramer Comparison letter are not different.

	2010		2011	
Species	Litter Depth (cm)	Tukey-Kramer Comparison	Litter Depth (cm)	Tukey-Kramer Comparison
Mallard	5.21 (0.29)	C	5.30 (0.29)	A
Gadwall	8.20 (0.57)	A	4.64 (1.16)	AB
Pintail[1]	4.90 (0.45)	CD	5.72 (0.41)	A
Shoveler[2]	6.99 (0.21)	B	6.99 (0.38)	A
BWT[3]	7.63 (0.22)	AB	6.82 (0.24)	A
Random	3.70 (0.16)	D	3.04 (0.12)	B

[1] Northern Pintail
[2] Northern Shoveler
[3] Blue-winged Teal

Table 19. Average litter depth (SE) at nest sites of the 5 most common nesting species and random locations during the late sampling period in 2010-11 in the Devils Lake Wetland Management District, North Dakota. Species with the same Tukey-Kramer Comparison letter are not different.

	2010		2011	
Species	Litter Depth (cm)	Tukey-Kramer Comparison	Litter Depth (cm)	Tukey-Kramer Comparison
Mallard	5.51 (0.38)	A	4.75 (0.23)	A
Gadwall	5.48 (0.17)	A	4.46 (0.15)	A
Pintail[1]	6.15 (0.58)	A	4.58 (0.52)	A
Shoveler[2]	6.62 (0.46)	A	4.45 (0.39)	A
BWT[3]	6.31 (0.32)	A	4.11 (0.25)	A
Random	3.70 (0.16)	B	3.04 (0.12)	B

[1] Northern Pintail
[2] Northern Shoveler
[3] Blue-winged Teal

Table 20. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success in multi-species native plantings and dense nesting cover in 2010-2011 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Type*Year, Obs[a], Obs^2 [b], Ht[c], Ht^2[d], Litter[e], Den[f]	6,702.51	0.00	0.71	10	6,682.51
Type*Year, Age[g], Obs, Obs^2, Ht, Ht^2, Litter, Den	6,704.46	1.94	0.27	11	6,682.45
Type*Year, Age, Ht, Ht^2, Litter, Den	6,711.47	8.96	0.01	9	6,693.47
Type*Year, Age, Obs, Ht, Ht^2, Litter, Den	6,713.36	10.85	0.01	10	6,693.36
Type*Year, Age, Obs, Ht, Ht^2, Litter, Area[h], Den	6,714.15	11.64	0.00	11	6,692.14
Type*Year, Age, Obs, Ht, Litter, Area, Den	6,714.45	11.94	0.00	10	6,694.45
Type*Year, Age, Obs, Hht, Ht^2, Den	6,715.05	12.53	0.00	9	6,697.04
Type*Year, Age, Obs, Ht, Ht^2, Litter, Den, Den^2 [i]	6,715.06	12.55	0.00	11	6,693.06
Type*Year, Age, Obs, Ht, Ht^2, Litter, Litter^2, Den, Den^2	6,716.40	13.89	0.00	12	6,692.40
Type*Year, Age, Obs, Litter, Area, Den	6,724.52	22.01	0.00	9	6,706.52
Type*Year, Age, Obs, Ht, Ht2, Litter, Area	6,738.99	36.48	0.00	10	6,718.98

Table 20. Continued. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success in multi-species native plantings and dense nesting cover in 2010-2011 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	wi	K	Deviance
Type*Year	6,770.60	68.09	0.00	4	6,762.60
Type+Year	6,823.90	121.38	0.00	3	6,817.90
Year	6,855.96	153.45	0.00	2	6,851.96
Type	6,902.30	199.79	0.00	2	6,898.30
Null	6,917.01	214.49	0.00	1	6,915.01

[a] Cover density around the nest
[b] Quadratic term for cover density around the nest
[c] Height of vegetation around the nest
[d] Quadratic term for height of vegetation
[e] Depth of litter at nest site
[f] Density of nests in field
[g] Age of nest when found
[h] Area of undisturbed grassland connected to field
[i] Quadratic term for density of nests in field

Table 21. Regression coefficients (β), standard errors, and lower and upper confidence intervals of the factors affecting daily survival rates (DSR) of nests in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Parameter	β	SE	LCI	UCI
Intercept	0.973	0.0142	0.969	0.977
Cover Type	0.539	0.0262	0.487	0.589
Year	0.535	0.0214	0.492	0.576
Type*Year	-0.265	0.0261	-0.318	-0.216
Obstruction	-0.459	0.0169	-0.492	-0.426
Height	0.518	0.0161	0.487	0.550
$Height^2$	-0.480	0.0050	-0.490	-0.470
Litter	0.515	0.0077	0.500	0.531
Area	-0.480	0.0090	-0.461	0.962
Density	-0.460	0.0087	-0.478	-0.443
$Density^2$	0.519	0.0213	-0.498	0.539

Table 22. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of northern pintails (*Anas acuta*) in 2010-11 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Obs[a], Ht[c], Ht[2 d]	451.42	0.00	0.40	4	443.41
Age[g], Obs, Ht, Ht[2]	452.22	0.79	0.27	5	442.19
Age, Obs, Obs[2 b], Ht, Ht[2]	454.14	2.72	0.10	6	442.11
Age, Ht, Ht[2]	454.73	3.31	0.08	4	446.72
Age, Obs, Obs[2], Ht	455.17	3.74	0.06	5	445.15
Age, Obs, Obs[2], Ht, Ht[2], Litter[e]	455.94	4.51	0.04	7	441.90
Age, Obs, Obs[2],Ht, Ht[2], Litter, Area[h]	457.85	6.42	0.02	8	441.80
Age, Obs, Obs[2], Ht, Ht[2], Litter, Area, Den[f]	458.15	6.72	0.01	9	440.08
Null	458.29	6.86	0.01	1	456.29

Table 22. Continued. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of northern pintails (*Anas acuta*) in 2010-11 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	wi	K	Deviance
Age, Obs, Obs^2	458.66	7.23	0.01	4	450.64
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den, Den^{2}[i]	460.12	8.70	0.01	10	440.05

[a] Cover density around the nest
[b] Quadratic term for cover density around the nest
[c] Height of vegetation around the nest
[d] Quadratic term for height of vegetation
[e] Depth of litter at nest site
[f] Density of nests in field
[g] Age of nest when found
[h] Area of undisturbed grassland connected to field
[i] Quadratic term for density of nests in field

Table 23. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of northern shovelers (*Anas clypeata*) in 2010-11 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Litter[e], Den[f]	1,046.58	0.00	0.57	3	1,040.57
Age[g], Litter, Den	1,048.55	1.97	0.21	4	1,040.54
Age, Obs[a], Litter, Den	1,050.43	3.85	0.08	5	1,040.42
Age, Obs, Obs^2 [b], Litter, Den	1,051.64	5.07	0.05	6	1,039.63
Age, Obs, Obs^2, Ht[c], Litter, Den	1,052.05	5.48	0.04	7	1,038.04
Age, Obs, Obs^2, Ht, Ht^2 [d] , litter, Den	1,053.03	6.46	0.02	8	1,037.02
Age, Obs, Obs^2, Ht, Ht^2, Den	1,054.14	7.56	0.01	7	1,040.12
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area [h], Den	1,054.98	8.40	0.01	9	1,036.96
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den, Den^2 [i]	1,055.85	9.28	0.01	10	1,035.83

Table 23. Continued. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of northern shovelers (*Anas clypeata*) in 2010-11 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Null	1,064.55	17.98	0.00	1	1,062.55
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area	1,066.81	20.23	0.00	8	1,050.79

[a] Cover density around the nest
[b] Quadratic term for cover density around the nest
[c] Height of vegetation around the nest
[d] Quadratic term for height of vegetation
[e] Depth of litter at nest site
[f] Density of nests in field
[g] Age of nest when found
[h] Area of undisturbed grassland connected to field
[i] Quadratic term for density of nests in field

Table 24. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of blue-winged teal (*Anas discors*) in 2010-11 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Obs[a], Litter[e], Area[h], Den[f], Den^2[i]	1,989.41	0.00	0.50	6	1,977.40
Age[g], Obs, Litter, Area, Den, Den^2	1,991.41	2.00	0.18	7	1,977.40
Age, Litter, Area, Den, Den^2	1,991.47	2.07	0.18	6	1,979.47
Age, Obs, Obs^2[a] , Litter, Area, Den, Den^2	1,992.81	3.40	0.09	8	1,976.80
Age, Obs, Obs^2, Ht[c], Litter, Area, Den, Den^2	1,994.72	5.31	0.04	9	1,976.70
Age, Obs, Obs^2, Ht, Ht^2[d], Litter, Area, Den, Den^2	1,996.71	7.30	0.13	10	1,976.69
Age, Obs, Obs^2, Ht, Ht^2, Litter, Den, Den^2	2,001.79	12.39	0.00	9	1,983.78
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den	2,004.82	15.41	0.00	9	1,986.80
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area	2,007.38	17.98	0.00	8	1,991.37

Table 24. Continued. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of blue-winged teal (*Anas discors*) in 2010-11 in Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Age, Obs, Obs^2, Ht, Ht^2, Area, Den, Den^2	2,007.55	18.15	0.00	9	1,989.54
Null	2,015.79	26.39	0.00	1	2,013.79

[a] Cover density around the nest
[b] Quadratic term for cover density around the nest
[c] Height of vegetation around the nest
[d] Quadratic term for height of vegetation
[e] Depth of litter at nest site
[f] Density of nests in field
[g] Age of nest when found
[h] Area of undisturbed grassland connected to field
[i] Quadratic term for density of nests in field

Table 25. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of gadwalls (*Anas strepera*) in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Ht[c], Ht^2[d], Den[f], Den^2[i]	1,897.61	0.00	0.38	5	1,887.60
Age[g], Ht, Ht^2, Den, Den^2	1,898.44	0.83	0.25	6	1,886.43
Age, Obs[a], Ht, Ht^2, Den, Den^2	1,899.46	1.85	0.15	7	1,885.45
Age, Obs, Obs^2[b], Ht, Ht^2, Den, Den^2	1,900.88	3.27	0.07	8	1,884.87
Age, Obs, Obs^2, Ht, Den, Den^2	1,901.30	3.69	0.06	7	1,887.29
Age, Obs, Obs^2, Ht, Ht^2, Litter[e], Den, Den^2	1,901.71	4.10	0.05	9	1,883.69
Age, Obs, Obs^2, Ht, Ht^2,Litter, Area[h], Den, Den^2	1,902.91	5.30	0.00	10	1,882.89
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area	1,904.60	6.99	0.00	7	1,890.59
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den	1,907.94	10.34	0.00	9	1,889.93

Table 25. Continued. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of gadwalls (*Anas strepera*) in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	wi	K	Deviance
Null	1,913.28	15.67	0.00	1	1,911.28
Age, Obs, Obs^2, Den, Den^2	3,278.94	1,381.34	0.00	5	3,268.94

[a] Cover density around the nest
[b] Quadratic term for cover density around the nest
[c] Height of vegetation around the nest
[d] Quadratic term for height of vegetation
[e] Depth of litter at nest site
[f] Density of nests in field
[g] Age of nest when found
[h] Area of undisturbed grassland connected to field
[i] Quadratic term for density of nests in field

Table 26. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of mallards (*Anas platyrhynchos*) in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	w_i	K	Deviance
Ht[c], Ht^2 [d], Den[f], Den^2 [i]	1,120.89	0.00	0.42	5	1,110.88
Age[g], Ht, Ht^2, Den, Den^2	1,121.46	0.56	0.31	6	1,109.44
Age, Obs[a], Ht, Ht^2, Den, Den^2	1,123.06	2.17	0.14	7	1,109.04
Age, Obs, Obs^2 [b], Ht, Ht^2, Den, Den^2	1,124.99	4.10	0.05	8	1,108.97
Age, Obs, Obs^2, Den, Den^2	1,126.86	5.97	0.02	6	1,114.85
Age, Obs, Obs^2, Ht, Ht^2, Litter[e], Den, Den^2	1,126.90	6.01	0.02	9	1,108.87
Age, Obs, Obs^2, Ht, Den, Den^2	1,127.15	6.26	0.00	7	1,113.13
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area[h], Den, Den^2	1,128.80	7.91	0.00	10	1,108.77
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area, Den	1,129.77	8.87	0.00	9	1,111.74

Table 26. Continued. Model selection results, including number of parameters (K) and model weight (w_i), used to examine factors affecting nest success of mallards (*Anas platyrhynchos*) in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

Model	AICc	Δ AICc	wi	K	Deviance
Age, Obs, Obs^2, Ht, Ht^2, Litter, Area	1,131.45	10.55	0.00	8	1,115.42
Null	1,140.26	19.37	0.00	1	1,138.26

[a] Cover density around the nest
[b] Quadratic term for cover density around the nest
[c] Height of vegetation around the nest
[d] Quadratic term for height of vegetation
[e] Depth of litter at nest site
[f] Density of nests in field
[g] Age of nest when found
[h] Area of undisturbed grassland connected to field
[i] Quadratic term for density of nests in field

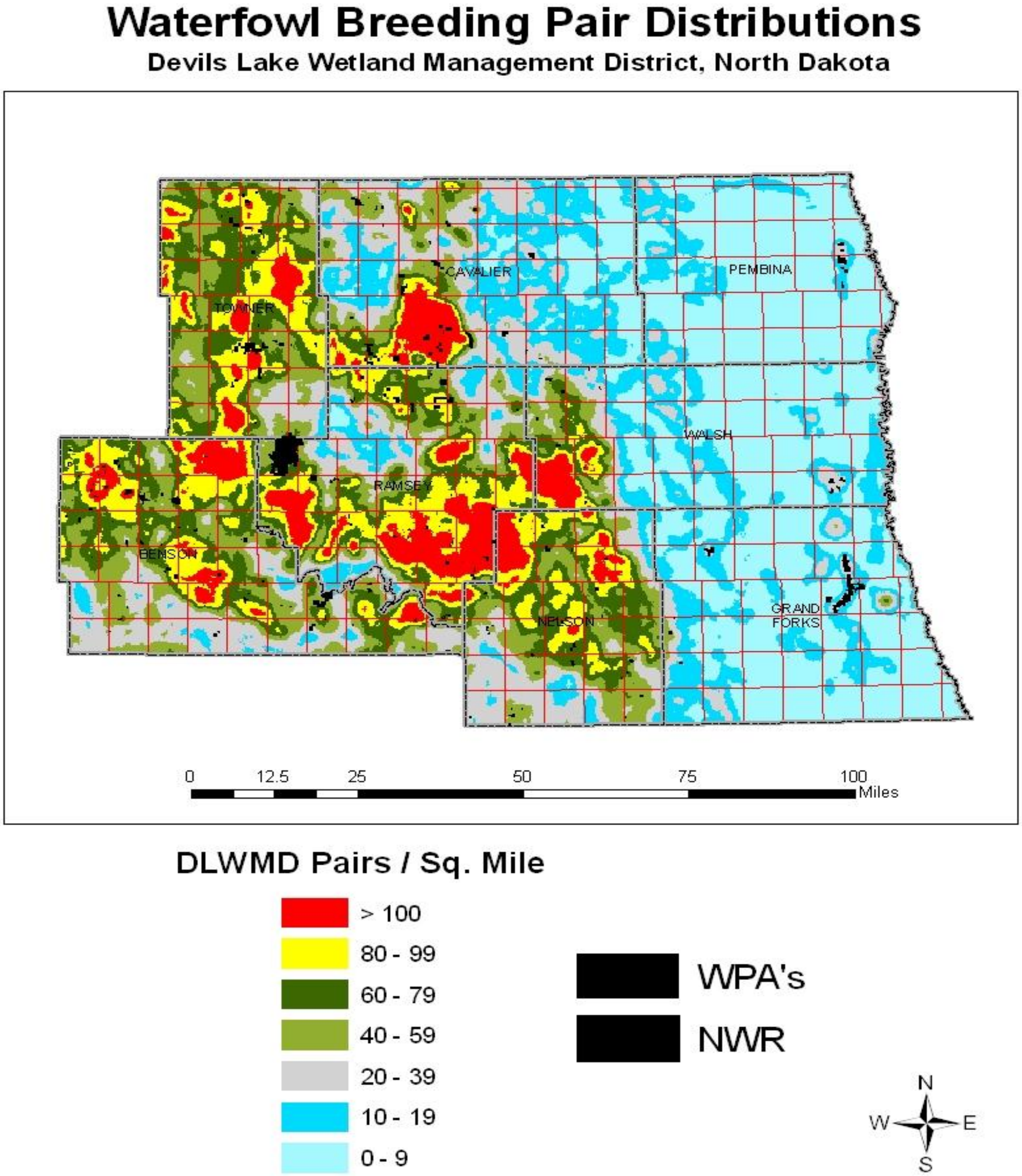

Figure 1. Map showing the number of breeding pairs per square mile in the Devils Lake Wetland Management District, North Dakota.

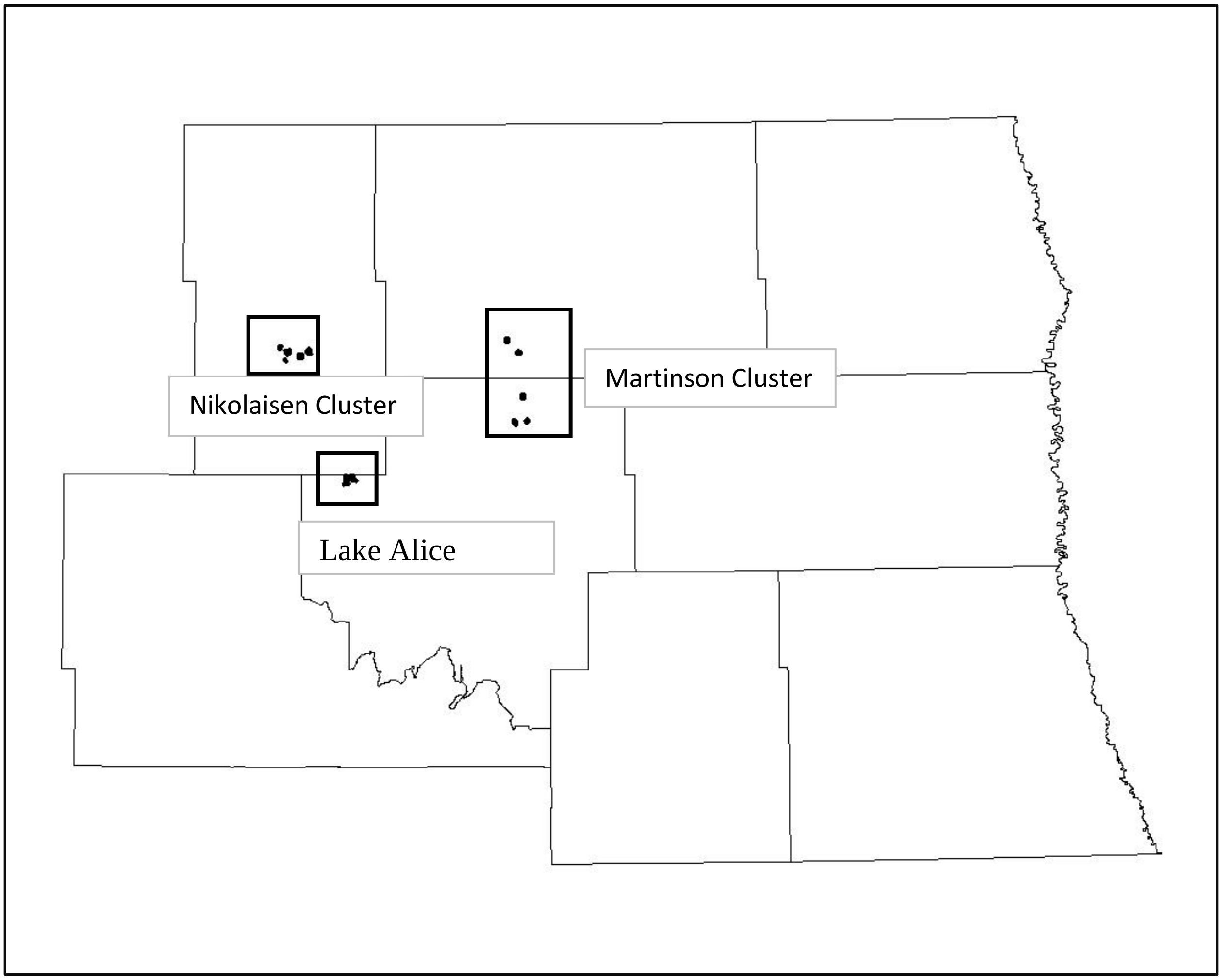

Figure 2. Map of study sites divided into clusters in the Devils Lake Wetland Management District, North Dakota.

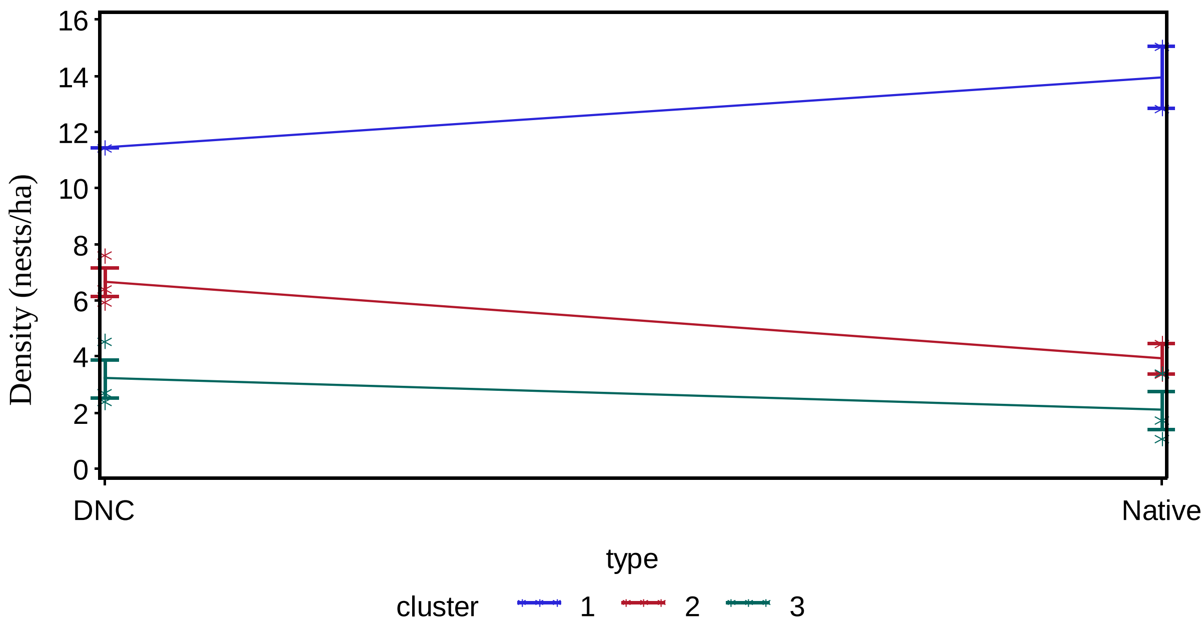

Figure 3. Cluster*type interaction for nest density during 2010 field season in Devils Lake Wetland Management District, North Dakota.

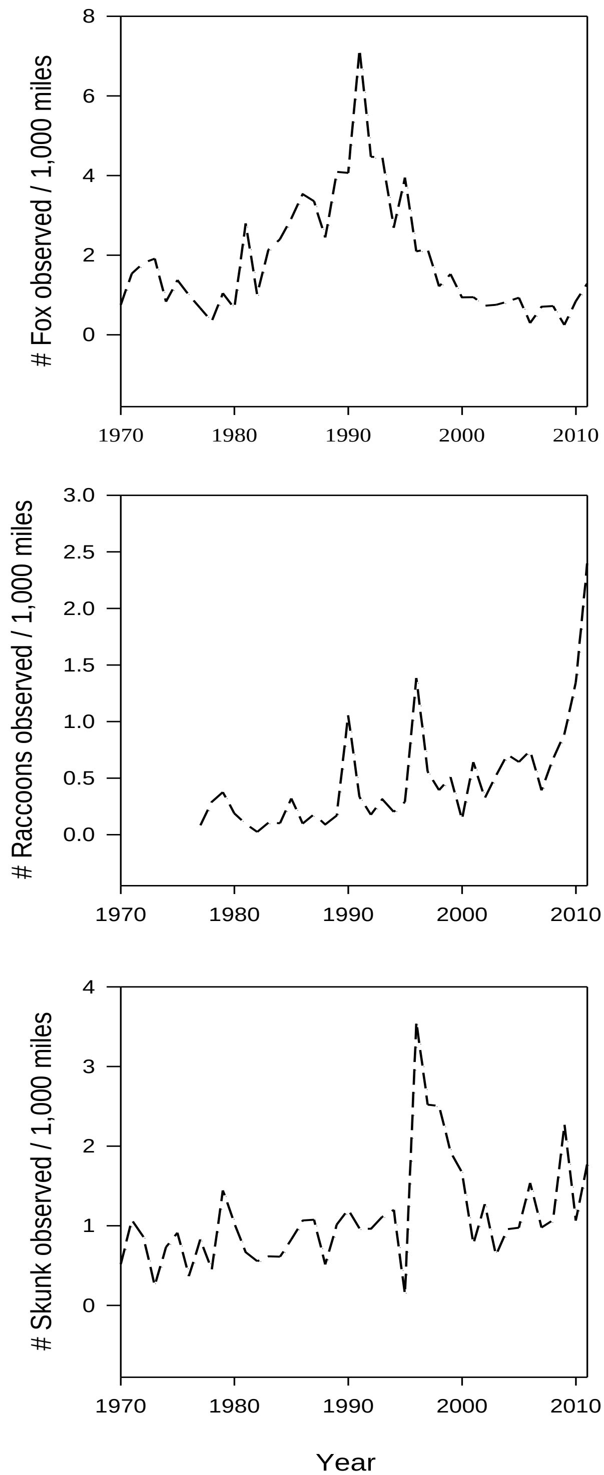

Figure 4. Number of predators observed during the North Dakota Rural Route Carrier survey for the Drift Prairie in northeastern North Dakota. (Data provided by North Dakota Game and Fish Department)

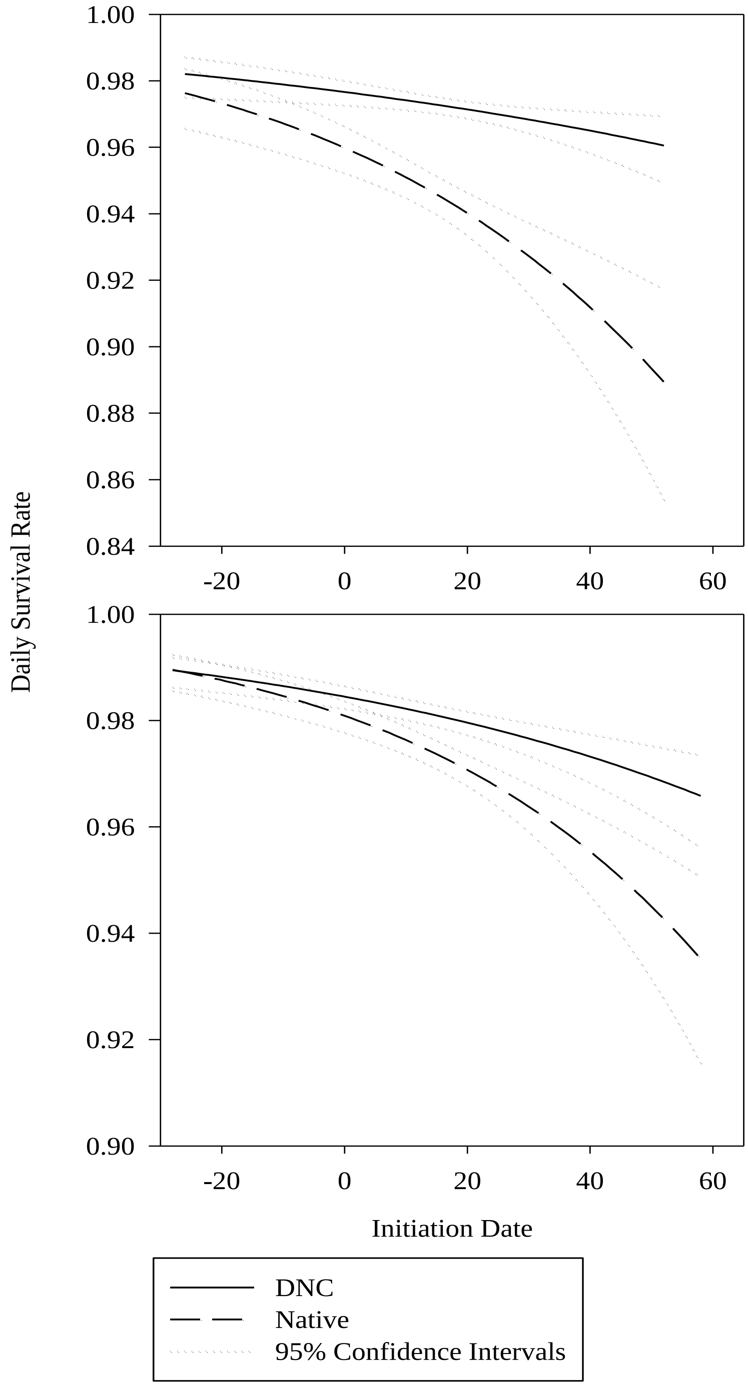

Figure 5. Estimated daily survival rate in relation to nest initiation date for nests in multi-species native plantings and dense nesting cover (DNC) in 2010 (below) and 2011 (above) in the Devils Lake Wetland Management District, North Dakota.

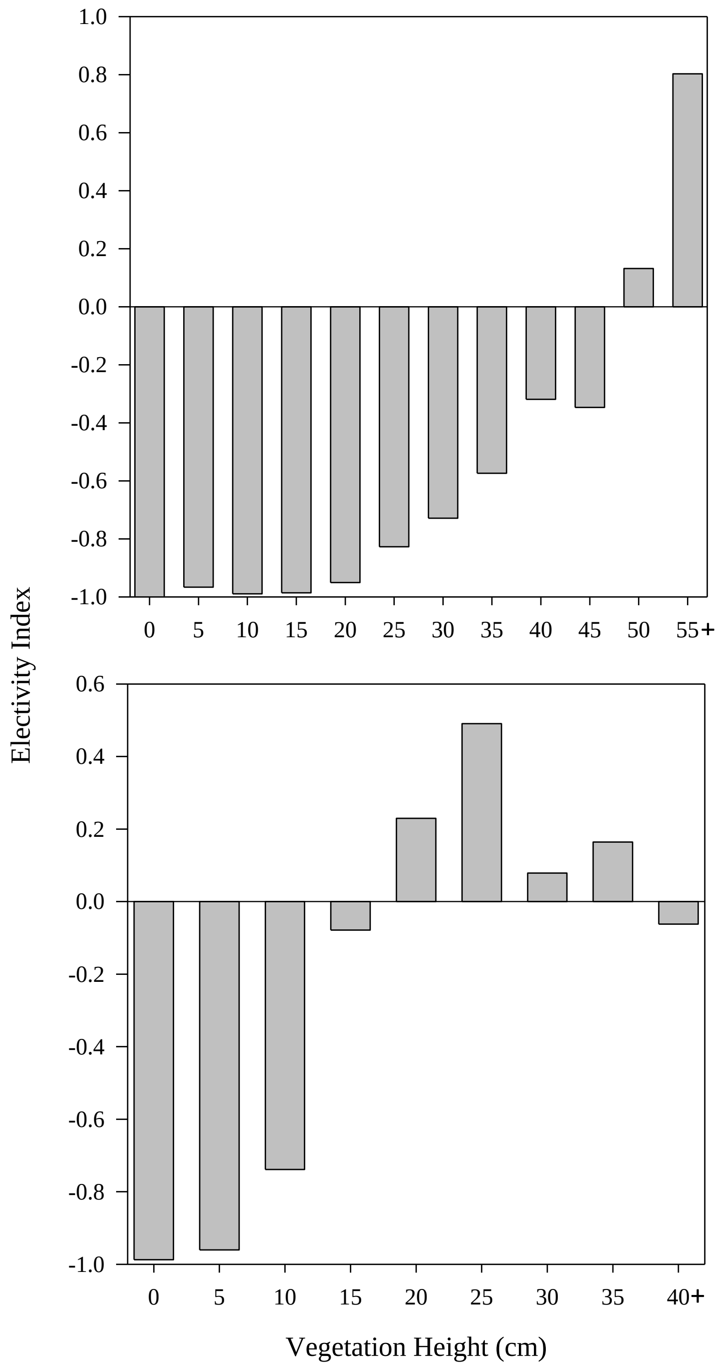

Figure 6. Electivity index for vegetation height during the early (below) and late (above) sampling periods in 2010-11 in the Devils Lake Wetland Management District, North Dakota. The selection differential is the proportion of nests found in a given vegetation height class subtracted from the proportion of random locations in that height class. A positive value indicates use of a height class more than it was available while a negative value indicates use of a height class less than it was available.

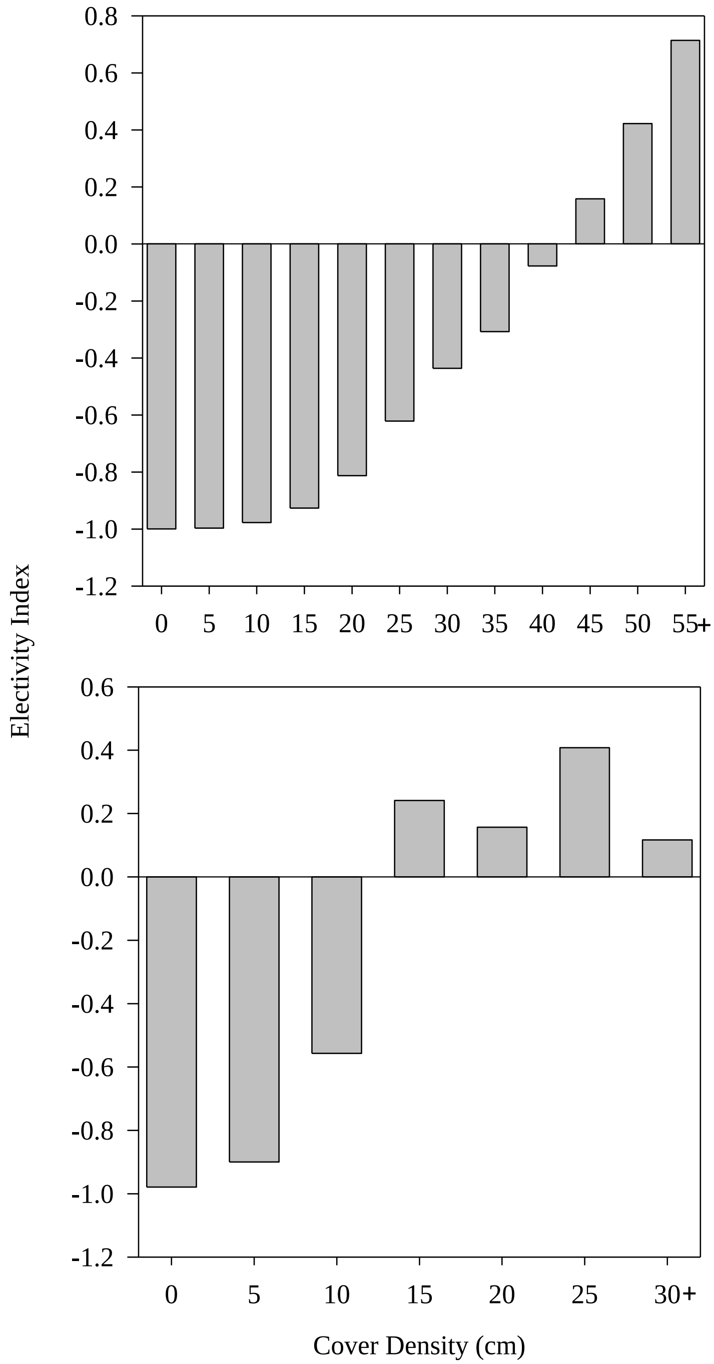

Figure 7. Electivity index for cover density during the early (below) and late (above) sampling periods in 2010-11 in the Devils Lake Wetland Management District, North Dakota. Selection differential is the proportion of nests found in a given cover density class subtracted from the proportion of random locations in that density class. A positive value indicates use of a density class more than it was available while a negative value indicates use of a density class less than it was available.

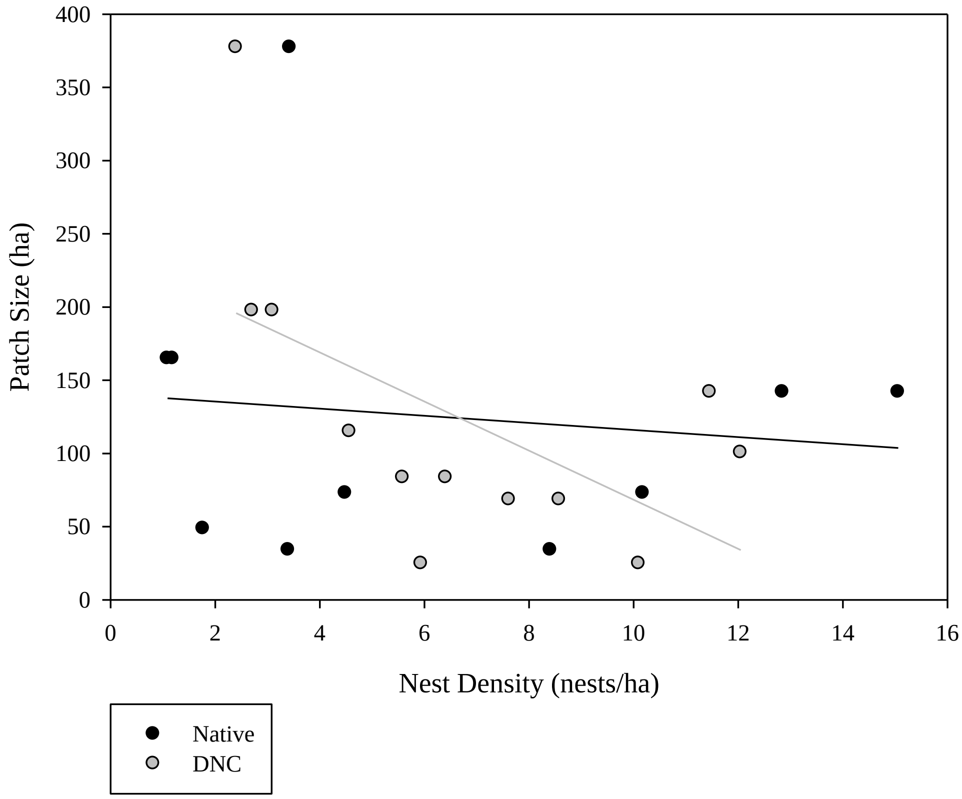

Figure 8. Relationship between nest density and patch size in multi-species native plantings and dense nesting cover (DNC) in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

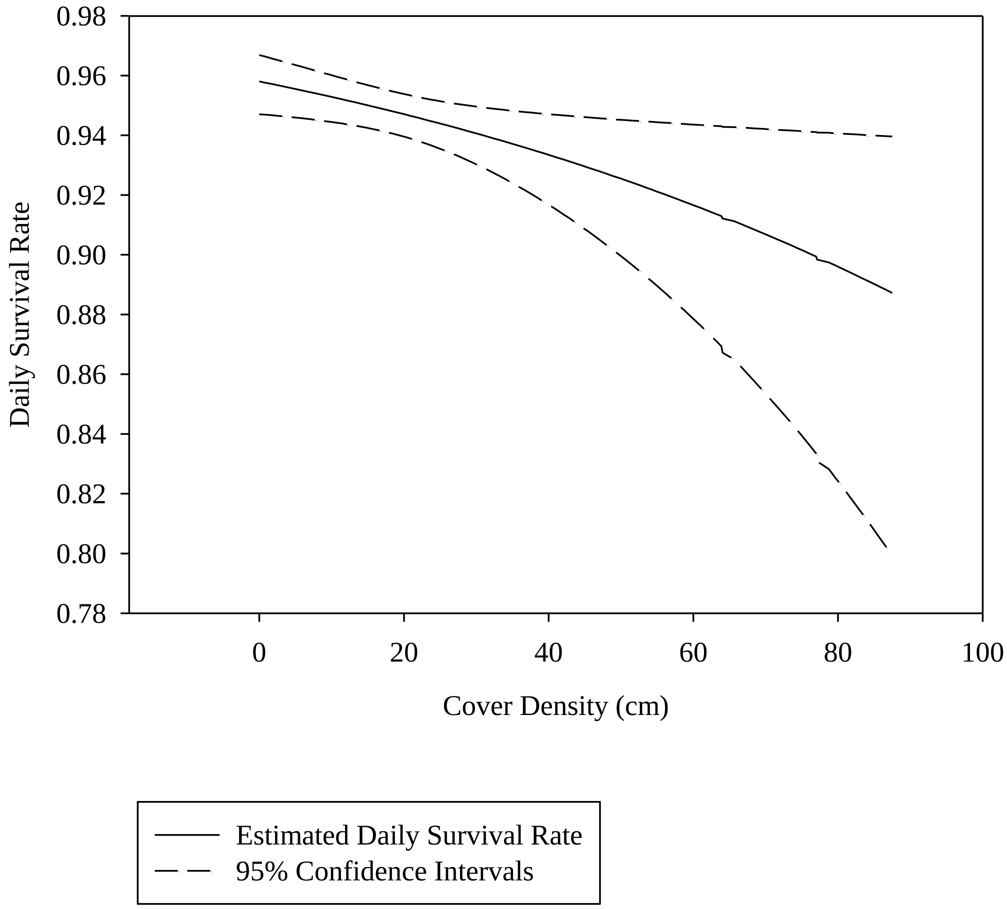

Figure 9. Estimated daily survival rate in relation to amount of cover density around nests in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

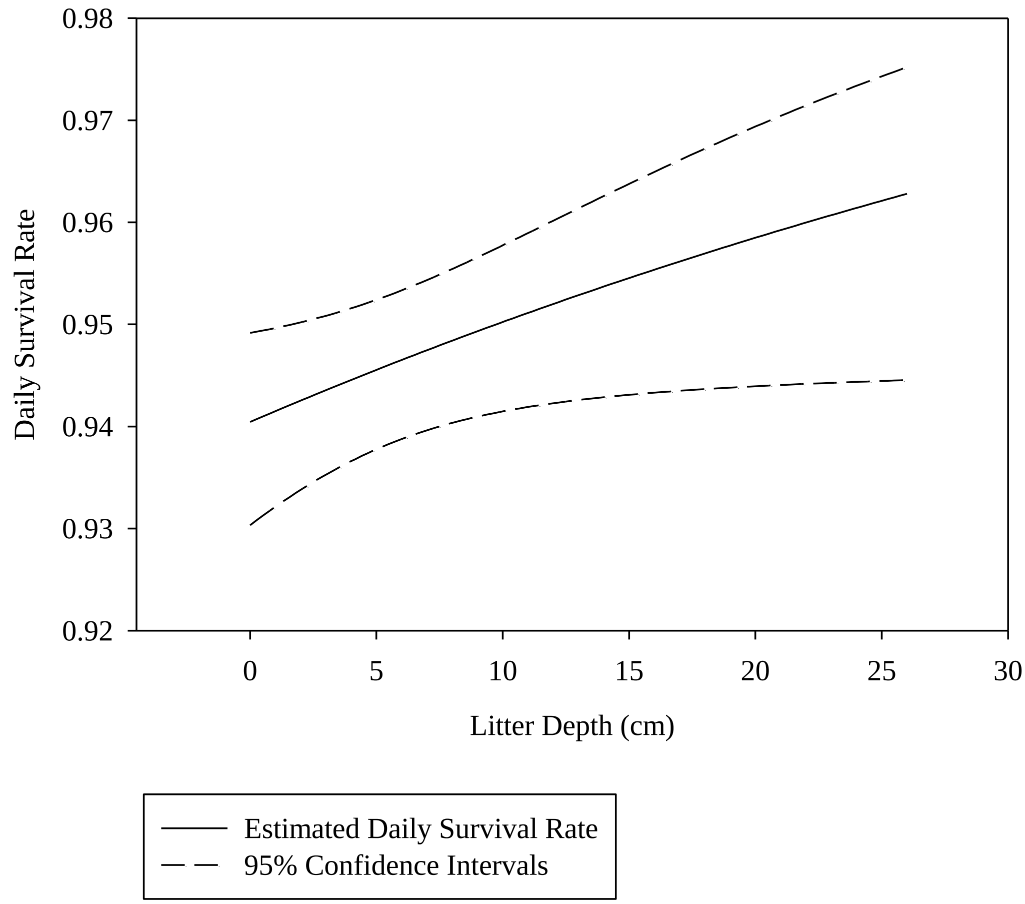

Figure 10. Estimated daily survival rate in relation to litter depth at nests in 2010–11 in the Devils Lake Wetland Management District, North Dakota.

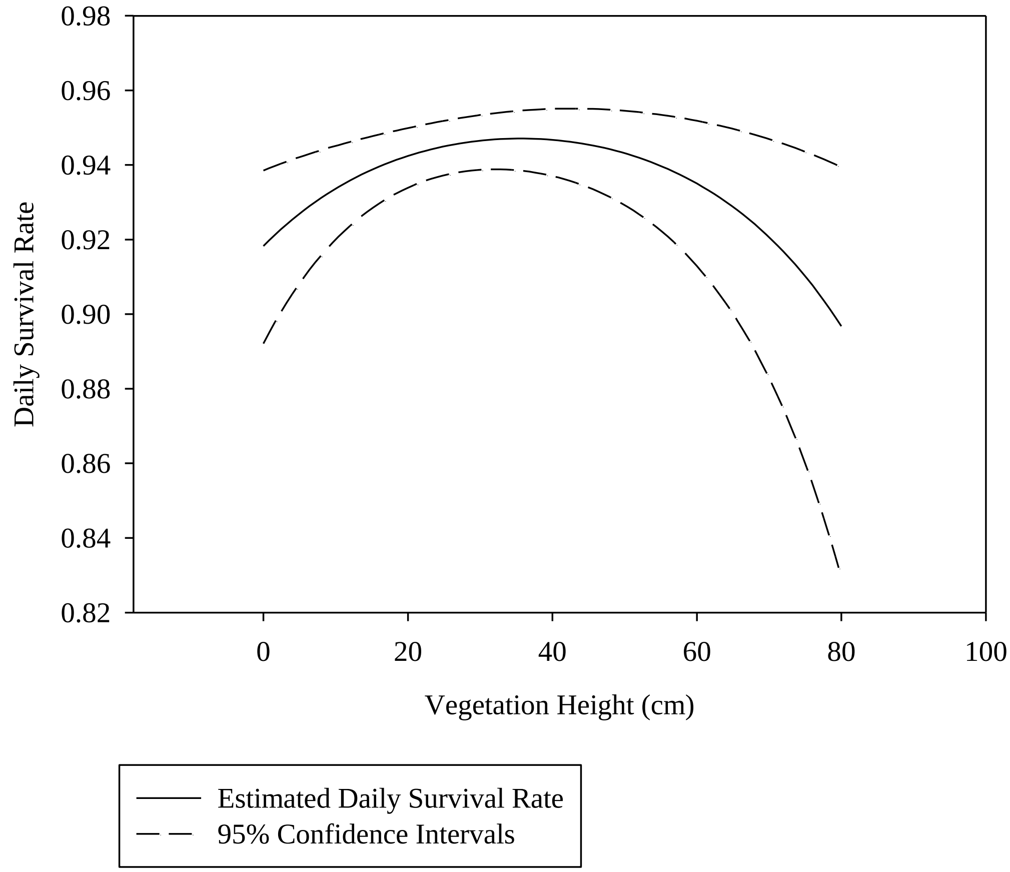

Figure 11. Estimated daily survival rate in relation to vegetation height around nests in 2010–11 in the Devils Lake Wetland Management District, North Dakota.

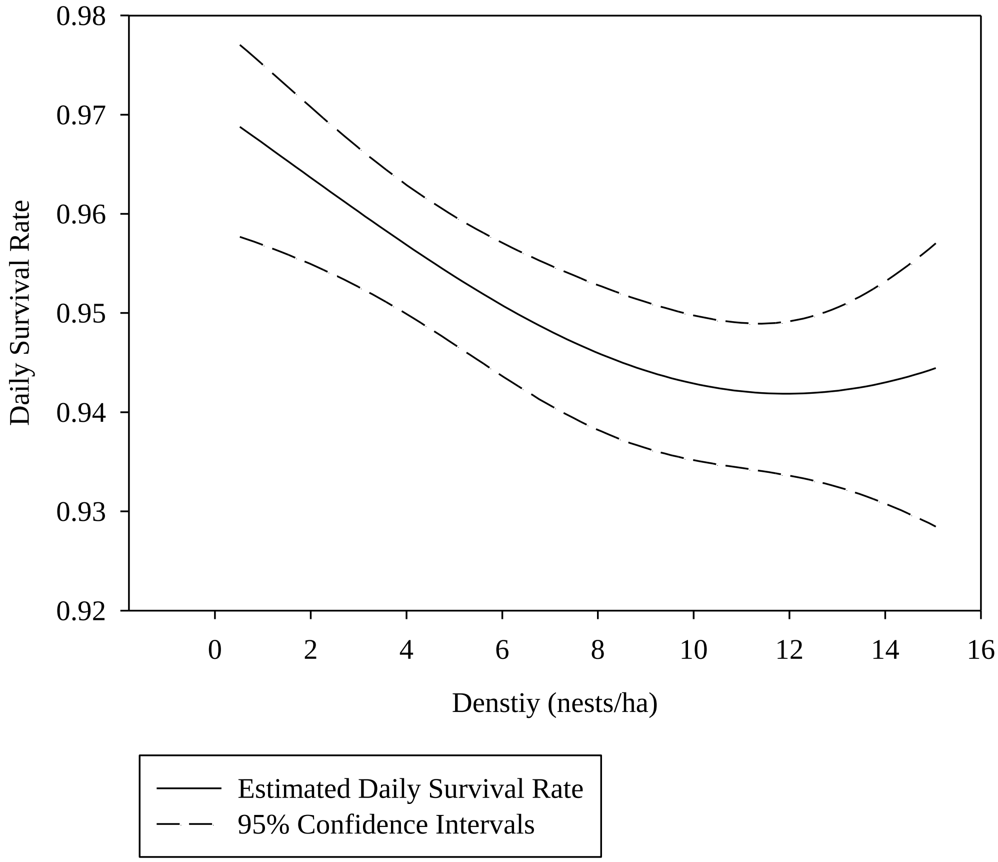

Figure 12. Estimated daily survival rate in relation to density of nests in field in 2010–11 in the Devils Lake Wetland Management District, North Dakota.

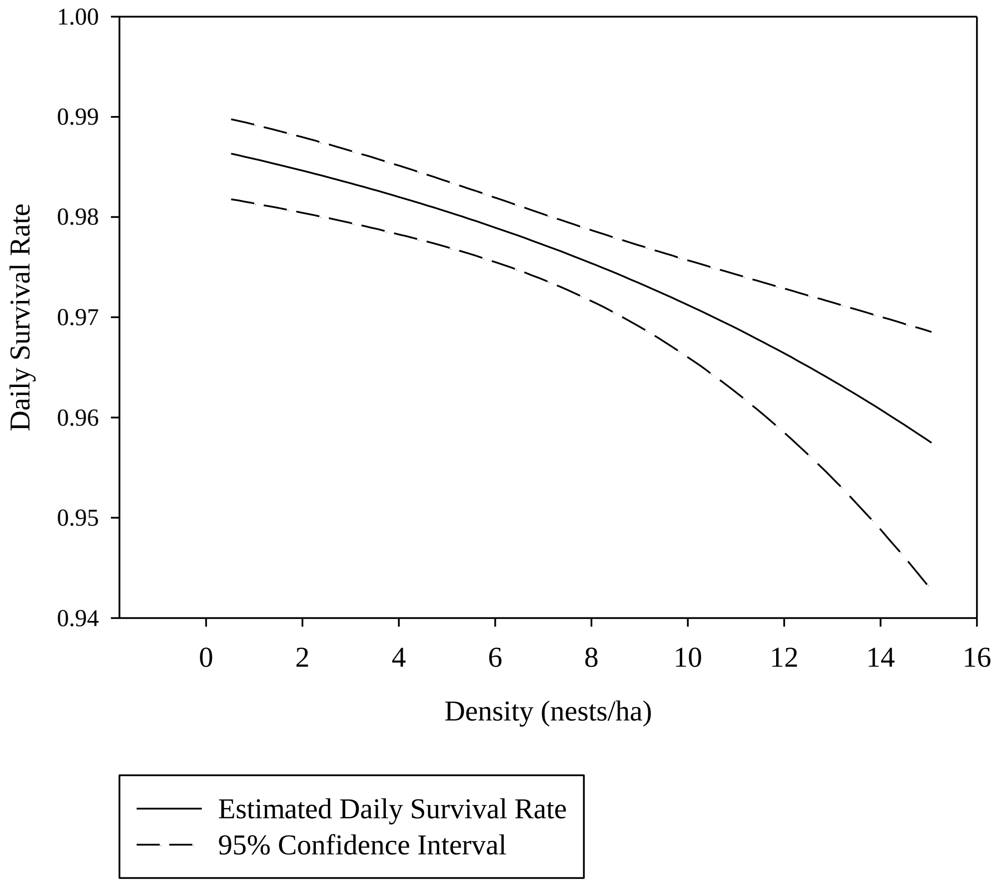

Figure 13. Estimated daily survival rate of northern shoveler (*Anas* clypeata) nests in relation to density of nests in field in 2010–11 in the Devils Lake Wetland Management District, North Dakota.

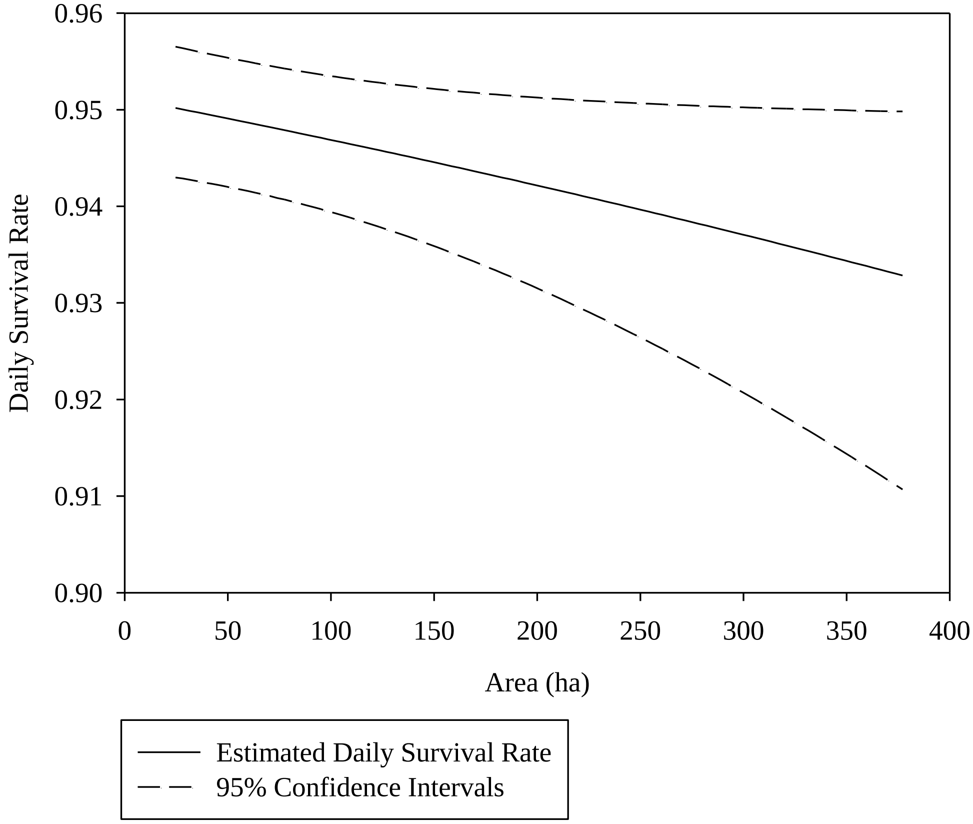

Figure 14. Estimated daily survival rate in relation to size of undisturbed grassland cover in 2010–11 in the Devils Lake Wetland Management District, North Dakota.

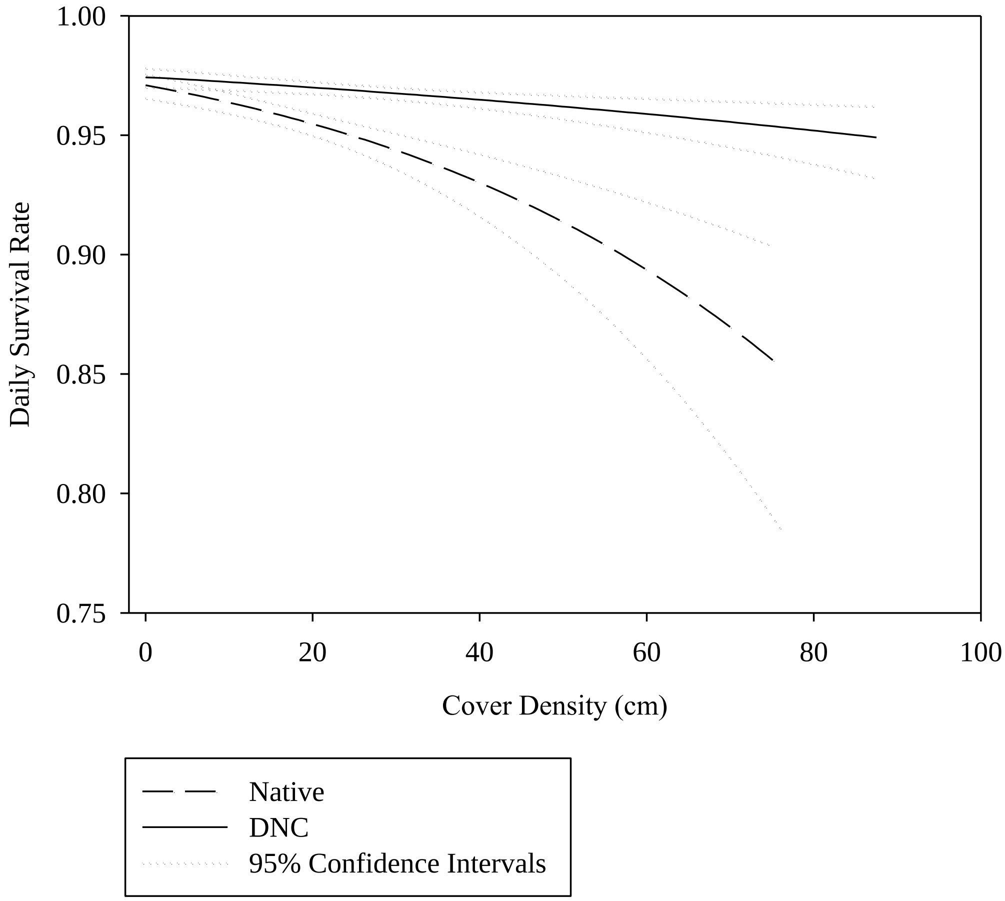

Figure 15. Estimated daily survival rate in relation to cover density in multi-species native plantings and dense nesting cover (DNC) in 2010-11 in the Devils Lake Wetland Management District, North Dakota.

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APPENDICES

Appendix A. List of plant species, type of plant, seeding rate, and per cent of mixture of each species planted in Toilet and Lake Alice North fields in the Devils Lake Wetland Management District, North Dakota, USA.

Species				
Common Name	Scientific Name	Type of Plant	PLS* lbs/Ac	% in Mixture
Big Bluestem	*Andropogon gerardii*	WSG[1]	0.4	5.0
Little Bluestem	*Schizachyruim scoparium*	WSG	0.1	2.0
Indiangrass	*Sorghastrum nutans*	WSG	0.6	8.0
Switchgrass	*Panicum virgatum*	WSG	0.5	10.0
Side-oats Grama	*Bouteloua curtipendula*	WSG	0.2	2.0
Blue Grama	*Bouteloua gracilis*	WSG	0.1	5.0
Canada Wildrye	*Elymus canadensis*	CSG[2]	0.4	5.0
Green Needlegrass	*Stipa viridula*	CSG	1.8	25.0
Porcupine Grass	*Hesperostipa spartea*	CSG	0.2	1.0
Western Wheatgrass	*Agropyron smithii*	CSG	1.8	15.0
Purple Prairie Clover	*Dalea purpurea*	Forb	0.1	3.0
Black-eyed Susan	*Rudbeckia serotina*	Forb	0.0	2.0
Maximillian Sunflower	*Helianthus maximiliani*	Forb	0.0	3.0
Prairie Coneflower	*Lepachys columnifera*	Forb	0.0	3.0
Blanket Flower	*Gaillardia aristata*	Forb	0.2	3.0
Wild Bergamont	*Monarda fistulosa*	Forb	0.0	1.0
Lewis Flax	*Linum lewisii*	Forb	0.1	2.0
Purple Coneflower	*Echinacea angustifolia*	Forb	0.2	2.0
Blazing Star	*Liatris punctata*	Forb	0.0	0.5
Lead Plant	*Amorpha canescens*	Forb	0.2	0.5
Shell-leaf Penstemon	*Penstemon grundiflorus*	Forb	0.0	1.0
Golden Alexander	*Zizia aurea*	Forb	0.0	1.0

* Pure Live Seed
[1] Warm-Season Grass
[2] Cool-season Grass

Appendix B. List of plant species, type of plant, seeding rate, and per cent of mixture of each species planted in Martinson Native field in the Devils Lake Wetland Management District, North Dakota, USA.

Species				
Common Name	Scientific Name	Type of Plant	PLS* lbs/Ac	% in Mixture
Big Bluestem	*Andropogon gerardii*	WSG[1]	0.60	-
Little Bluestem	*Schizachyruim scoparium*	WSG	0.30	-
Indiangrass	*Sorghastrum nutans*	WSG	0.40	-
Sideoats Grama	*Bouteloua curtipendula*	WSG	0.40	-
Blue Grama	*Bouteloua gracilis*	WSG	0.10	-
Swithgrass	*Panicum virgatum*	WSG	0.30	-
Prairie Dropseed	*Sporobolus heterolepis*	WSG	0.10	-
Porcupine Grass	*Hesperostipa spartea*	WSG	0.70	-
Green Needlegrass	*Stipa viridula*	CSG[2]	2.50	-
Western Wheatgrass	*Agropyron smithii*	CSG	1.40	-
Canada Wildrye	*Elymus canadensis*	CSG	0.40	-
Black-eyed Susan	*Rudbeckia serotina*	Forb	0.01	-
Blanket Flower	*Gaillardia aristata*	Forb	0.10	-
Leadplant	*Amorpha canescens*	Forb	0.30	-
Maximilian Sunflower	*Helianthus maximiliani*	Forb	0.01	-
Purple Coneflower	*Echinacea angustifolia*	Forb	0.10	-
Prairie Coneflower	*Lepachys columnifera*	Forb	0.20	-
Purple Prairie Clover	*Dalea purpurea*	Forb	0.04	-
Wild Bergamont	*Monarda fistulosa*	Forb	0.02	-
Blazing Star	*Liatris punctata*	Forb	0.02	-
Lewis Flax	*Linum lewisii*	Forb	0.03	-
Canada Milkvetch	*Astragalus canadensis*	Forb	0.04	-
Golden Alexander	*Zizia aurea*	Forb	0.03	-

*Pure Live Seed
[1] Warm-Season Grass
[2] Cool-season Grass

Appendix C. List of plant species, type of plant, seeding rate, and per cent of mixture of each species planted in Dahl field in the Devils Lake Wetland Management District, North Dakota, USA.

Species				
Common Name	Scientific Name	Type of Plant	PLS* lbs/Ac	% in Mixture
Big Bluestem	*Andropogon gerardii*	WSG[1]	-	50
Indiangrass	*Sorghastrum nutans*	WSG	-	< 5
Little Bluestem	*Schizachyruim scoparium*	WSG	-	< 5
Sideoats Grama	*Bouteloua curtipendula*	WSG	-	< 5
Prairie Dropseed	*Sporobolus heterolepis*	WSG	-	< 5
Switchgrass	*Panicum virgatum*	WSG	-	< 5
Prairie Cordgrass	*Spartina pectinata*	WSG	-	< 5
Canda Wildrye	*Elymus canadensis*	CSG[2]	-	< 5
Sweetclover	*Melilotus spp.*	Forb	-	< 5
Wild Sunflower	*Helianthus annuus*	Forb	-	< 5
Tall Meadow Rue	*Thalictrum pubescens*	Forb	-	< 5
Blazing Star	*Liatris punctata*	Forb	-	< 5
Stiff Goldenrod	*Solidago rigida*	Forb	-	< 5
Golden Alexander	*Zizia aurea*	Forb	-	< 5
Canda Thistle	*Cirsium arvense*	Forb	-	< 1
Other Crop Seed	-	-	-	5

* Pure Live Seed
[1] Warm-Season Grass
[2] Cool-season Grass

Appendix D. List of plant species, type of plant, seeding rate, and per cent of mixture of each species planted in Register West field in the Devils Lake Wetland Management District, North Dakota, USA.

Species				
Common Name	Scientific Name	Type of Plant	PLS* lbs/Ac	% in Mixture
Big Bluestem	*Andropogon gerardii*	WSG[1]	0.80	10
Little Bluestem	*Schizachyruim scoparium*	WSG	0.40	7
Indiangrass	*Sorghastrum nutans*	WSG	0.50	6
Switchgrass	*Panicum virgatum*	WSG	0.40	9
Side-oats Grama	*Bouteloua curtipendula*	WSG	0.20	3
Green Needlegrass	*Stipa viridula*	CSG[2]	0.30	4
Western Wheatgrass	*Agropyron smithii*	CSG	1.30	11
Slender Wheatgrass	*Agropyron trachycaulum*	CSG	0.60	9
Needle-and-Thread	*Stipa comata*	CSG	0.40	4
Canada Wildrye	*Elymus canadensis*	CSG	0.50	6
Black-eyed Susan	*Rudbeckia serotina*	Forb	0.02	3
Purple Prairie Clover	*Lepachys columnifera*	Forb	0.20	4
Blanket Flower	*Gaillardia aristata*	Forb	0.40	5
Maximilian Sunflower	*Helianthus maximiliani*	Forb	0.10	6
Prairie Coneflower	*Lepachys columnifera*	Forb	0.10	6
Canda Milkvetch	*Astragalus canadensis*	Forb	1.40	4
Blazing Star	*Liatris punctata*	Forb	0.20	3

* Pure Live Seed
[1] Warm-Season Grass
[2] Cool-season Grass

Appendix E. List of plant species, type of plant, seeding rate, and per cent of mixture of each species planted in Cami field in the Devils Lake Wetland Management District, North Dakota, USA.

Species				
Common Name	Scientific Name	Type of Plant	PLS* lbs/Ac	% in Mixture
Big Bluestem	*Andropogon gerardii*	WSG[1]	0.40	5
Little Bluestem	*Schizachyruim scoparium*	WSG	0.40	8
Indiangrass	*Sorghastrum nutans*	WSG	0.40	5
Switchgrass	*Panicum virgatum*	WSG	0.20	5
Side-oats Grama	*Bouteloua curtipendula*	WSG	0.40	5
Blue Grama	*Bouteloua gracilis*	WSG	0.10	5
Canada Wildrye	*Elymus canadensis*	CSG[2]	0.40	5
Green Needlegrass	*Stipa viridula*	CSG	0.40	5
Porcupine Grass	*Hesperostipa spartea*	CSG	0.20	1
Needle-and-Thread	*Stipa comata*	CSG	0.10	1
Western Wheatgrass	*Agropyron smithii*	CSG	0.40	3
Slender Wheatgrass	*Agropyron trachycaulum*	CSG	0.10	2
Purple Prairie Clover	*Dalea purpurea*	Forb	0.40	10
White Prairie Clover	*Dalea candida*	Forb	0.20	5
Black-eyed Susan	*Rudbeckia serotina*	Forb	0.04	5
Maximillian Sunflower	*Helianthus maximiliani*	Forb	0.10	4
Prairie Coneflower	*Lepachys columnifera*	Forb	0.10	5
American Vetch	*Vicia americana*	Forb	0.70	2
Blanket Flower	*Gaillardia aristata*	Forb	0.40	5
Wild Bergamont	*Monarda fistulosa*	Forb	0.10	2
Lewis Flax	*Linum lewisii*	Forb	0.10	2
Purple Coneflower	*Echinacea angustifolia*	Forb	0.20	2
Stiff Goldenrod	*Solidago rigida*	Forb	0.10	2
Blazing Star	*Liatris punctata*	Forb	0.10	1
Canada Milk Vetch	*Astragalus canadensis*	Forb	0.04	1
Prairie Rose	*Rosa arkansana*	Forb	0.60	2
Lead Plant	*Amorpha canescens*	Forb	0.60	2

* Pure Live Seed
[1] Warm-Season Grass
[2] Cool-season Grass

Appendix F. List of plant species, type of plant, seeding rate, and per cent of mixture of each species planted in Halvorson field in the Devils Lake Wetland Management District, North Dakota, USA.

Species				
Common Name	Scientific Name	Type of Plant	PLS* lbs/Ac	% in Mixture
Little Bluestem	*Schizachyruim scoparium*	WSG[1]	-	35
Switchgrass	*Panicum virgatum*	WSG	-	35
Bluestem spp.	*Andropogon* spp.	WSG	-	< 1
Prairie Sandreed	*Calamovilfa longifolia*	WSG	-	< 1
Slender Wheatgrass	*Agropyron trachycaulum*	CSG[2]	-	15
Western Wheatgrass	*Agropyron smithii*	CSG	-	15
Sweetclover	*Melilotus* spp.	Forb	-	< 1

* Pure Live Seed
[1] Warm-Season Grass
[2] Cool-season Grass

Appendix G. List of plant species, type of plant, seeding rate, and per cent of mixture of each species planted in dense nesting cover fields in the Devils Lake Wetland Management District, North Dakota, USA.

Species				
Common Name	Scientific Name	Type of Plant	PLS* lbs/Ac	% in Mixture
Tall Wheatgrass	*Thinopyrum ponticum*	CSG[1]	6.1	45
Intermediate Wheatgrass	*Agropyron intermedium*	CSG	2.5	25
Vernal Alfalfa	*Medicago sativa*	Forb	1.3	20
Yellow Sweetclover	*Melilotus officinalis*	Forb	0.5	10

* Pure Live Seed
[1] Cool-season Grass

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