PREDATOR SELECTION OF PRAIRIE LANDSCAPE FEATURES AND ITS RELATION TO DUCK NEST SUCCESS

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Abstract: Mammalian predation is an important cause of mortality for breeding waterfowl in the U.S. Northern Great Plains, and yet we know little about the selection of prairie habitats by predators or how this influences nest success in grassland nesting cover. We selected 2 41.4-km² study areas in both 1996 and 1997 in North Dakota, USA, with contrasting compositions of perennial grassland. A study area contained either 15–20% perennial grassland (Low Grassland Composition [LGC]) or 45–55% perennial grassland (High Grassland Composition [HGC]). We used radiotelemetry to investigate the selection of 9 landscape cover types by red fox (Vulpes vulpes) and striped skunk (Mephitis mephitis), while simultaneously recording duck nest success within planted cover. The cover types included the edge and core areas of planted cover, wetland edges within planted cover or surrounded by cropland, pastureland, hayland, cropland, roads, and miscellaneous cover types. Striped skunks selected wetland edges surrounded by agriculture over all other cover types in LGC landscapes (P-values for all pairwise comparisons were <0.05). Striped skunks also selected wetland edges surrounded by agriculture over all other cover types in HGC landscapes (P < 0.05), except for wetland edges within planted cover (P = 0.12). Red foxes selected the edge and core areas of planted cover, as well as wetland edges within planted cover in LGC landscapes (i.e., they were attracted to the more isolated patches of planted cover). However, in HGC landscapes, red foxes did not select interior areas of planted cover (i.e., core areas of planted cover and wetland edges in planted cover) as frequently as edges of planted cover (P < 0.05). Red foxes selected core areas of planted cover more frequently in LGC than in HGC landscapes (P < 0.05) and selected pastureland more frequently in HGC than in LGC landscapes (P < 0.05). Furthermore, red foxes selected the isolated patches of planted cover more than pastureland in LGC landscapes (P < 0.05). Duck nest success was greater in HGC landscapes than in LGC landscapes for planted-cover core (P < 0.0001), planted-cover edge (P < 0.001) and planted-cover-wetland edge (P < 0.001). Both the increased amount of planted-cover core area and the increased pastureland selection in HGC landscapes may have diluted predator foraging efficiency in the interior areas of planted cover and contributed to higher nest success in HGC landscapes. Our observations of predator cover-type selection not only support the restoration and management of large blocks of grassland but also indicate the influence of alternative cover types for mitigating nest predation in the Prairie Pothole Region.

Key words: habitat fragmentation, habitat selection, landscape composition, Mephitis mephitis, nest success, nesting habitat, North Dakota, Prairie Pothole Region, predation, red fox, striped skunk, Vulpes vulpes, waterfowl.

Mammalian predation is an important factor influencing nest success of waterfowl in the Prairie Pothole Region of the northern Great Plains (Klett et al. 1988, Johnson et al. 1989, Sargeant and Raveling 1992, Sargeant et al. 1993). Although most mammalian predators are habitat generalists (Fritzell 1978, Sargeant et al. 1984, Greenwood 1986), little is known about how landscape composition affects the ability of predators to find waterfowl nests. Conversion of native grasslands to agricultural use has led to loss and fragmentation of breeding cover for upland waterfowl (Sugden and Beyersbergen 1984, Batt et al. 1989), which likely has led to changes in the relationship between predator movements and waterfowl nesting success. We studied red foxes and striped skunks—common waterfowl predators (Korschgen 1959, Sargeant 1972, Sargeant et al. 1984, Greenwood 1986) with the potential to range widely across many different cover types and exhibit different movement patterns.

Theory predicts that predators should select a cover type in a mosaic agricultural landscape.

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based on the required resources’ rate of return relative to that of surrounding cover types (Stephens and Krebs 1986). Predators will remain in, or frequently revisit, a patch as long as the rate of gain in resources remains above the average for that cover type (Charnov 1976, Stephens and Krebs 1986). In a prairie landscape dominated by agriculture, grassland habitat contains food resources attractive to predators (Sargeant et al. 1984, Pasitschniak-Arts and Messier 1998, Greenwood et al. 1999) and is surrounded by agricultural cover types that are less attractive to predators. Predators should spend more time in isolated grassland patches in a fragmented agricultural landscape because of the increased energy investment required to reach these patches (Charnov 1976) and less time in the interior of large grassland blocks in less fragmented landscapes due to increased foraging effort (Emlen 1966).

Predator movement patterns may be influenced by the physiognomic characteristics of grassland patches (Andren 1995, Ims 1995). Small or linearly shaped patches have proportionally less interior “core area” and more edge than large, block-shaped patches (Temple 1986). Nests near grassland edges may be vulnerable to either direct or incidental predation (Gates and Gysel 1978, Angelstam 1986, Vickery et al. 1992). For grassland nesting birds, the landscape’s grassland edge density can affect hen mortality due to predation (Schmitz and Clark 1999), and the amount of grassland core area can be important in predicting nest success (Pasitschniak-Arts and Messier 1996, Clark et al. 1999). The extent to which the grassland edge or core areas affect nest success may depend on the amount of grassland in the landscape (Donovan et al. 1997, Clark et al. 1999).

In addition to edges around planted cover, edges around wetlands also may influence predator movement. Wetland edges and wet meadows contain many prey species that are attractive to skunks (Greenwood et al. 1999, Lariviere and Messier 2000). However, no one has examined whether the landscape context of wetland edges influences predator movement. If grassland habitat is attractive to predators, then wetland edges surrounded by grassland may not be selected as frequently as wetland edges surrounded by cropland due to predators spending more time in the adjacent grassland.

We examined predator selection of cover types while simultaneously estimating waterfowl nest success in landscapes with contrasting amounts of grassland. Our objective was to determine whether waterfowl nesting success is related to predator cover-type selection. We predicted that in landscapes with low grassland composition, predators would disproportionately select isolated patches of grassland (both edge and interior areas of grassland patches) relative to the surrounding agricultural cover types. Patches highly selected by predators are more likely to be efficiently searched. In contrast, we predicted that in landscapes with a high grassland composition, predators would be less efficient in searching the larger blocks of grassland. As a consequence, waterfowl would have higher nest success in both edge and interior areas of grassland in landscapes with a high grassland composition.

**STUDY AREAS**

In 1996 and 1997, we selected 2 41.4-km² study areas each year with contrasting amounts of perennial grassland (planted cover, pastureland, hayland) in the Prairie Pothole Region of central North Dakota, USA. Cover types within the Prairie Pothole Region have been previously described by upland habitat (Cowardin et al. 1986, Reynolds et al. 1994) or wetland type (Cowardin et al. 1979). We selected LGC study areas in Litchville, North Dakota (Svea Township in Barnes County) in 1996 and Bowdon, North Dakota (Berlin Township in Wells County) in 1997. These study areas contained isolated patches of perennial grassland surrounded by cropland. Litchville contained 66.9% cropland, 12.5% planted cover, 2.3% pastureland, and 0.3% hayland. Bowdon contained 56.4% cropland, 13.8% planted cover, 2.7% pastureland, and 3.2% hayland.

In contrast, we selected HGC study areas in Medina, North Dakota (Iosco Township in Stutsman County) in 1996 and Hurdsfield, North Dakota (Silver Lake Township in Wells County) in 1997. These study areas contained large patches of perennial grassland adjacent to cropland. Medina contained 34.3% cropland, 22.1% planted cover, 19.0% pastureland, and 4.1% hayland. Hurdsfield contained 23.0% cropland, 22.5% planted cover, 27.8% pastureland, and 1.5% hayland. Cropland on all study areas was planted in either row crops (corn, beans, sunflowers) or grain crops (wheat and barley).

We used data from the National Wetland Inventory (NWI; U.S. Fish and Wildlife Service, St. Petersburg, Florida, USA) to classify wetlands on study areas. The NWI classifications were converted to Stewart and Kantrud (1971) classifications by the Habitat and Population Evaluation Team (U.S. Fish and Wildlife Service, Bismarck, North Dakota, USA).
North Dakota, USA). Wetlands in these study areas were predominantly temporary and seasonal.

All study areas also included a square-mile road system (<2% of each study area) and other cover types (each <1.0%) including farmsteads, trees, and other miscellaneous cover types. The Medina study area included a predator exclosure (2.4%), which contained planted cover enrolled in the Conservation Reserve Program (CRP) and hayland.

**METHODS**

**Capture**

We captured foxes and skunks in April and May (1996 and 1997) and in June (1997) using livetraps for skunks and either snares with stops or leg hold traps for foxes. A professional trapper from Wildlife Services (U.S. Department of Agriculture, Bismarck, North Dakota) assisted in capturing foxes. We trapped intensively and systematically across all study areas with the goal of capturing all resident animals of both species. All captured study animals were radiomarked with telemetry transmitters (Advanced Telemetry Systems, Isanti, Minnesota, USA) containing a 1-hr mortality switch. The collars weighed approximately 60 g for skunks and 110 g for foxes. All trapping and handling procedures followed recommendations by the American Society of Mammalogists (1987), the Northern Prairie Wildlife Research Center’s Animal Care and Use Guidelines, and were approved by the Iowa State University Committee on Animal Care.

**Radiotelemetry**

We sampled daytime (0800–2000) activity by recording 1 location for each animal Monday through Saturday. Considering the nocturnal nature of these predators (Verts 1967, Ables 1969), we recorded their movements intensively at night (2000–0800). We sampled their nocturnal movement 3 times each week. To ensure complete study-area coverage and sampling of all animals, we divided each study area into 4 quadrants and systematically rotated our sampling among each of the quadrants. We recorded the frequency and duration each animal was tracked to minimize bias in our tracking effort.

Locations for a sampled animal were recorded every 10–15 min. We estimated locations from 2 or more bearings using vehicle-mounted null-peak directional antennas. Bearings were taken from permanent telemetry stations positioned along roads or at other accessible locations. We estimated Universal Transverse Mercator (UTM) coordinates for each station using a Global Positioning System receiver. For animal locations, UTM coordinates and their 95% error ellipses were estimated using LOCATE II software (Nams 1990). For locations based on 2 bearings, we estimated error ellipses using a prior estimate of the bearing standard deviation determined for each crew member based on 2 field tests given before and midway through the field season. For locations based on >2 bearings, we estimated error ellipses from the location’s bearing standard deviation.

We examined the statistical distribution of the error ellipses and deleted any location with an error ellipse >3.0 times the interquartile range above the 75% quantile (an “extreme outlier;” Devore and Peck 1986:94). Animals with <20 locations (13 skunks and 4 foxes) were considered undersampled and were not used in analyses.

**Habitat and Landscape Variables**

We recorded land-cover data for each study area (including a 1.6-km wide surrounding border) from low altitude aerial photography and videography. Cover types were digitized and classified using the Map and Image Processing System (MicroImages, Lincoln, Nebraska, USA). Cover classifications were verified by ground observations. We used ARC/INFO (Environmental Systems Research Institute 1994) for management and analysis of the land-cover data.

We delineated 9 cover types for each study area: planted-cover core, planted-cover edge, planted-cover–wetland edge, agriculture–wetland edge, pastureland, hayland, cropland, roads (paved and gravel), and miscellaneous cover types. We delineated the edge and core of planted cover and not other grassland types since duck nest success was assessed only in planted cover.

We defined planted cover as areas seeded to perennial grasses and forbs and enrolled in the CRP, the Water Bank Program (WBP), or federal Waterfowl Production Areas (WPA). Our definition of a planted cover patches is similar to Sovada et al. (2000: Fig. 2), except that we allowed gravel and paved roads to divide adjacent areas of planted cover into separate patches. We defined planted-cover edge as 50 m on either side of the boundary of a patch of planted cover. Therefore, the core area of the planted cover was upland planted cover >50 m from the boundary inside a patch of planted cover.

We divided wetland edges into planted-cover–wetland edge (areas 50 m from the boundary of a wetland that was within planted cover)
and agricultural–wetland edge (areas 50 m from the boundary of a wetland not within planted cover). If a wetland edge intersected planted-cover edge, the cover type was defined as wetland edge instead of planted-cover edge. The open water portions of wetlands were excluded from analysis because these areas were not available to skunks and foxes.

Pastureland contained grazed perennial grasses. Hayland contained perennial grasses that were disturbed by mowing. The miscellaneous category included farmyards, trees (small woodlots or shelterbelts), fallow agricultural land, islands, land not in agricultural use, and a predator enclosure in Medina. The predator enclosure was kept separate from other grassland types. It was classified as a miscellaneous cover type in the analysis of predator cover-type selection and was not included in the nest success estimation.

Statistical Analysis

We evaluated fox and skunk cover-type selection using compositional analysis (Aitchison 1982, Aebischer et al. 1993). By focusing the analyses on compositions, animals became the observational unit of our analyses rather than individual locations.

We used a buffering technique to estimate the cover-type composition available to each predator. Although a home range frequently has been used to define cover types available to an animal (Aebischer et al. 1993), we recorded locations intensely along nightly movement paths that would skew the shape and size of a home-range estimator. Therefore, we defined available cover types based on a series of concentric buffers around the mean UTM coordinate for each animal. The buffering technique avoided assumptions necessary for calculating a home range and is independent of individual behavior. We buffered at 500, 1,000, 2,000, and 3,000 m distances. These distances were determined by examining the distribution of locations for each animal. We used multivariate analysis of variance (MANOVA; Rencher 1995) to simultaneously compare the relative cover-type selections within a landscape type for foxes and skunks separately at each buffer distance. The smallest buffer distance that indicated nonrandom use by both foxes and skunks gave the most conservative estimate of available cover.

If we observed a buffer distance with nonrandom use by foxes and skunks, we then used a MANOVA (Rencher 1995) to simultaneously compare the relative selection of cover types between landscape types for each species at that buffer distance. If we found a significant difference between landscapes, we compared the log-transformed selection ratios for each of the cover types separately using a t-test (SAS Institute 1990).

We tested for differences between each pair of cover types (Aebischer et al. 1993) and ranked them by level of use. Cover types were ranked from 1 (lowest selection) to 9 (highest selection). We computed a series of t-tests to determine which cover types contributed most to nonrandom use (Rencher and Scott 1990, Aebischer et al. 1993).

We chose an alpha level of 0.10 to evaluate the MANOVA tests using Wilks’ Λ as the test criteria and an alpha level of 0.05 to evaluate the t-tests. Because each animal did not have the same number of locations, we weighted the observations in the MANOVA, rank tests and t-tests by the square root of the number of locations.

To illustrate the selection probability for each cover type (i = 1, …, D) among individuals (k = 1, …, n) by each species (s = fox or skunk) in the different landscape types (l = LGC or HGC landscape), we computed standardized selection ratios (Manly et al. 1993:40) such that:

\[ B_{isl} = \frac{G_{isl}}{\sum G_{isl}} \]

where \( G_{isl} \) is the geometric mean of the selection ratios \( w_{isl} \) among individuals for each species in each landscape type. A selection ratio \( w_{isl} \) is the proportion of a cover type used divided by the proportion of a cover type that is available to an individual. Therefore, the geometric mean of the selection ratios is:

\[ G_{isl} = \text{antilog} \left( \frac{1}{n} \sum_{k=1}^{n} \ln w_{isl,k} \right) \]

We used geometric means so that the standardized selection ratios \( B_{isl} \) would correspond to the ranks of the cover types that are based on the log scale.

We illustrated the relative strength of selection among the cover types in Figs. 1–4 using the inverse of the number of resources (i.e., 1/9 = 0.11; Krebs 1999:478). Values >0.11 indicate relatively high levels of selection and values <0.11 indicate relatively low levels of selection.

Nest Success

We focused assessment of duck nest success in planted cover. We searched for waterfowl nests from early May to mid-July using procedures simi-
lar to Higgins et al. (1969). Each field was searched 3 times in 1996 and 4 times in 1997. Further details of procedures to find and monitor nests are given in Horn (2000). We estimated daily survival rates (DSR) using procedures developed by Mayfield (1975) and modified by Johnson (1979). We used program CONTRAST (Hines and Sauer 1989) to compare estimates of DSRs in the 3 planted-cover types between and within landscape types.

RESULTS

Radiotelemetry

We recorded 23,592 predator locations over the 2 field seasons. We did not use locations with an error ellipse >11.8 ha. The median area for error ellipses was 1.1 ha. The data were highly skewed toward a few locations with large errors. The final data set contained 3,295 day locations and 18,616 night locations for 114 individuals (Litchville, 6 foxes and 22 skunks; Bowdon, 7 foxes and 22 skunks; Medina, 5 foxes and 17 skunks; Hurdsfield, 10 foxes and 25 skunks).

Habitat Selection

Study areas in LGC landscapes contained smaller more isolated patches of planted cover than study areas in HGC landscapes. As a result, study areas in LGC landscapes contained smaller compositions of core area and edge of planted cover (Table 1). We found 26 planted-cover patches on LGC landscape study areas, ranging from 2 to 192 ha (45 ± 10.6 ha; \( \bar{x} \pm SE \)). In contrast, HGC landscape study areas contained 22 planted-cover patches, ranging from 4 to 606 ha (153 ± 36.6 ha; \( \bar{x} \pm SE \)).

The 2,000-m buffer distance was the smallest buffer distance that revealed nonrandom use for both foxes and skunks on both landscape types (Table 2). This buffer distance also closely reflected the range of movement for both foxes and skunks. The 500-m buffer contained only 36.7% of fox and skunk locations, while the 1,000-m buffer contained 75.3%, the 2,000-m buffer contained 97.8%, and the 3,000-m buffer contained 99.4% of the locations. The 3,000-m buffer added a large amount of cover but contributed few additional locations.

The selection of cover types differed between landscape types for foxes (Wilks’ \( \Lambda = 0.48; 8, 19 \) df; \( P < 0.05 \)), but not for skunks (Wilks’ \( \Lambda = 0.85; 8, 77 \) df; \( P = 0.103 \)). Foxes selected planted-cover core more in LGC than in HGC landscapes and pastureland more in HGC than in LGC landscapes (Table 3).

For foxes in LGC landscapes, the selection of planted-cover core ranked highest among cover types (Fig. 1). Selection of the 3 planted-cover types (i.e., edge, core, and planted-cover–wetland edge) were all highly ranked and did not differ from each other in the level of selection (\( P = 0.36–0.96 \)). Planted-cover core was not different from agricultural–wetland edge (\( P = 0.41 \)) or cropland (\( P = 0.06 \)). However, selection of planted-cover cores by foxes was greater than pastureland (\( P < 0.01 \)), hayland (\( P < 0.05 \)), roads (\( P < 0.001 \)), and miscellaneous cover types (\( P < 0.05 \)).

For skunks in LGC landscapes, both the rank and the level of selection for agricultural–wetland edge were all highly ranked and did not differ from each other in the level of selection (\( P = 0.0229–0.0001 \)). The selection of planted-cover core was different from agricultural–wetland edge (\( P = 0.0280 \)), hayland (\( P < 0.05 \)), and miscellaneous cover types (\( P < 0.001 \)).

Table 2. Multivariate analysis of variance (MANOVA) tests evaluating cover-type selection by red fox and striped skunk for 4 buffer distances on study areas with low grassland composition (LGC) and high grassland composition (HGC) in North Dakota, USA, 1996–1997.

<table>
<thead>
<tr>
<th>Landscape type</th>
<th>Buffer distance (m)</th>
<th>LGC Fox (n = 13)</th>
<th>Wilks’ ( \Lambda )</th>
<th>( P )</th>
<th>HGC Fox (n = 15)</th>
<th>Wilks’ ( \Lambda )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500</td>
<td>1,000</td>
<td>2,000</td>
<td>3,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LGC</td>
<td>Fox (n = 13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wilks’ ( \Lambda )</td>
<td>0.2409</td>
<td>0.0170</td>
<td>0.0868</td>
<td>0.0568</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( P )</td>
<td>0.2362</td>
<td>0.0005</td>
<td>0.0265</td>
<td>0.0098</td>
<td></td>
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<tr>
<td></td>
<td>Skunk (n = 44)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Wilks’ ( \Lambda )</td>
<td>0.6248</td>
<td>0.5675</td>
<td>0.2541</td>
<td>0.2246</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( P )</td>
<td>0.0229</td>
<td>0.0061</td>
<td>0.0001</td>
<td>0.0001</td>
<td></td>
<td></td>
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<tr>
<td>HGC</td>
<td>Fox (n = 15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wilks’ ( \Lambda )</td>
<td>0.3011</td>
<td>0.4327</td>
<td>0.1479</td>
<td>0.1009</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( P )</td>
<td>0.1830</td>
<td>0.0347</td>
<td>0.0232</td>
<td>0.0069</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Skunk (n = 42)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wilks’ ( \Lambda )</td>
<td>0.7019</td>
<td>0.5990</td>
<td>0.3073</td>
<td>0.1767</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( P )</td>
<td>0.1105</td>
<td>0.0156</td>
<td>0.0001</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
land edges were greater than all other cover types ($P < 0.05$ for all comparisons; Fig. 2). The selection of cropland was greater than pastureland and hayland ($P < 0.05$). Selection of the 3 planted-cover types was not different from other cover types (except agricultural–wetland edges).

For foxes in HGC landscapes, selection of planted-cover edge was ranked highest among cover types but differed only from planted-cover core ($P < 0.05$) and planted-cover–wetland edges ($P < 0.05$; Fig. 3). Planted-cover core and planted-cover–wetland edges are associated with the interior areas of planted cover. Selection for the 3 planted-cover types was not different from other cover types ($P = 0.15$–0.94). In contrast to foxes in LGC landscapes, the selection of planted-cover cores did not differ from pastureland ($P = 0.47$) even though pastureland was ranked much higher in HGC landscapes. Agricultural–wetland edges were ranked highest for skunk in HGC landscapes and selection of agricultural–wetland edges was greater than all other cover types ($P < 0.05$ for all comparisons), except planted-cover–wetland edges ($P = 0.12$; Fig. 4). The selection of planted-cover core areas

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**Table 3. Comparisons between log-transformed selection ratios ($\bar{x}$ and SE) for red foxes in different cover types between landscapes with low grassland composition (LGC) or high grassland composition (HGC) in North Dakota, USA, 1996–1997.**

<table>
<thead>
<tr>
<th>Cover type</th>
<th>LGC</th>
<th>SE</th>
<th>HGC</th>
<th>SE</th>
<th>$t$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted cover–core</td>
<td>0.24</td>
<td>0.221</td>
<td>-2.18</td>
<td>0.888</td>
<td>-2.38</td>
<td>0.025</td>
</tr>
<tr>
<td>Planted cover–edge</td>
<td>-0.19</td>
<td>0.512</td>
<td>-0.39</td>
<td>0.459</td>
<td>-0.29</td>
<td>0.776</td>
</tr>
<tr>
<td>Planted cover–wetland edge</td>
<td>-0.15</td>
<td>0.482</td>
<td>-2.06</td>
<td>0.898</td>
<td>-1.75</td>
<td>0.091</td>
</tr>
<tr>
<td>Agricultural–wetland edge</td>
<td>-0.04</td>
<td>0.184</td>
<td>-0.71</td>
<td>0.709</td>
<td>-0.82</td>
<td>0.417</td>
</tr>
<tr>
<td>Pastureland</td>
<td>-3.48</td>
<td>0.853</td>
<td>-1.12</td>
<td>0.633</td>
<td>2.26</td>
<td>0.032</td>
</tr>
<tr>
<td>Hayland</td>
<td>-2.37</td>
<td>0.886</td>
<td>-3.20</td>
<td>0.832</td>
<td>-0.68</td>
<td>0.502</td>
</tr>
<tr>
<td>Cropland</td>
<td>-0.33</td>
<td>0.109</td>
<td>-1.71</td>
<td>0.891</td>
<td>-1.39</td>
<td>0.177</td>
</tr>
<tr>
<td>Roads</td>
<td>-4.49</td>
<td>0.999</td>
<td>-1.72</td>
<td>0.930</td>
<td>2.01</td>
<td>0.055</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>-2.37</td>
<td>0.983</td>
<td>-1.82</td>
<td>0.973</td>
<td>0.39</td>
<td>0.700</td>
</tr>
</tbody>
</table>

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**Fig. 1. Standardized selection ratios (B) for red foxes in low grassland composition landscapes in North Dakota, USA, 1996–1997. Values within the bars are the rank of each cover type. Cover types with the same letter do not differ (P > 0.05). The solid line represents the level of selection if all cover types were selected at random.**
Fig. 2. Standardized selection ratios (B) for striped skunk in low grassland composition landscapes in North Dakota, USA, 1996–1997. Values within the bars are the rank of each cover type. Cover types with the same letter do not differ (P > 0.05). The solid line represents the level of selection if all cover types were selected at random.

Fig. 3. Standardized selection ratios (B) for red foxes in high grassland composition landscapes in North Dakota, USA, 1996–1997. Values within the bars are the rank of each cover type. Cover types with the same letter do not differ (P > 0.05). The solid line represents the level of selection if all cover types were selected at random.
was less than planted-cover–wetland edges ($P < 0.05$), but it was not different from use of planted-cover edges ($P = 0.14$). Unlike skunks in LGC landscapes, the selection of cropland did not differ from pastureland ($P = 0.82$) or hayland ($P = 0.73$). The selection of the 3 planted-cover types did not differ from cropland ($P = 0.12–0.94$), pastureland ($P = 0.20–0.80$), or hayland ($P = 0.39–0.81$).

**Nest Success**

We computed the DSR for 1,449 duck nests in planted cover. We found no differences among the 3 planted-cover types in LGC landscapes ($\chi^2 = 0.56$, df = 2, $P = 0.76$) or HGC landscapes ($\chi^2 = 2.72$, df = 2, $P = 0.26$). However, nest success was greater in HGC landscapes than in LGC landscapes for each of the planted-cover types, as well as for all 3 planted-cover types combined (Table 4).

**DISCUSSION**

Foxes were attracted to the isolated patches of planted cover in landscapes with a low grassland composition, but rarely used the interior areas of planted cover in landscapes with a high grassland composition. Skunks were attracted to agricultural–wetland edges and did not respond to the differing compositions of planted cover. The higher level of selection for a cover type could result from intensive searching within a local area over a short time (Tinbergen et al. 1967) or from multiple return visits over the breeding season.

As predicted, foxes frequently selected isolated patches of planted cover (both edge and interior areas) in LGC landscapes. This increased selection of planted cover (whether for foraging, denning, or marking a territory) gave foxes a greater opportunity to find nests either directly or incidentally (Vickery et al. 1992). This is consistent with our observation of lower nest success in LGC landscapes than in HGC landscapes for all 3 cover types associated with planted cover.

The low level of selection by foxes for interior areas of planted cover in HGC landscapes may have resulted from increased interior area in large blocks of planted cover that decreased the overall ratio of use to availability. The low level of selection also may be due to increased availability of other perennial grassland cover types such as pastureland that potentially contained resources that were attractive alternatives to planted cover. Fox selection of pastureland was greater in HGC landscapes than in LGC landscapes. The...
effect of these selection patterns may be viewed as a dilution of searching efficiency by foxes in the interior areas of planted cover resulting in the increased nest success in HGC landscapes.

The most striking characteristic of skunks was the strong selection for agricultural–wetland edges. Wetland edges usually contain food resources (both vertebrates and invertebrates) attractive to skunks (Greenwood et al. 1999, Lariviere and Messier 2000). Lariviere and Messier (2000) observed that skunks are attracted to wetland edges in prairie landscapes. However, we also observed that skunks did not select wetland edges within planted cover as strongly as agricultural–wetland edges. This suggests that the landscape context of the wetland edge influenced selection by skunks. Upland areas of planted cover could provide alternative resources to wetland edges that are attractive to skunks.

In contrast to foxes, skunks did not show a strong selection for features of planted cover in LGC landscapes, which supports the observation by Lariviere and Messier (2000) of low managed nesting habitat use by skunks. This pattern of selection suggests that skunks will not have as great an influence as foxes on nest success in planted cover. They will, however, be an important predator of waterfowl that commonly nest near wetlands.

Despite similar selection levels for planted-cover edge by foxes and skunks on both landscape types, nest survival estimates in planted-cover edge were greater in HGC than in LGC landscapes, and did not differ from the interior planted-cover types in HGC landscapes. We examined this apparent discrepancy by comparing DSR estimates in planted-cover edge for each of the 4 study areas. Medina (a HGC landscape) had greater nest survival in planted-cover edge ($0.95 \pm 0.005$, DSR $\pm$ SE, $n = 172$) than Litchville ($0.87 \pm 0.02$, $n = 34$, $P < 0.001$), Bowdon ($0.92 \pm 0.01$, $n = 65$, $P < 0.05$), or Hurdsfield ($0.92 \pm 0.02$, $n = 36$, $P < 0.05$). No difference in nest survival was detected in planted-cover edge among Litchville, Bowdon, and Hurdsfield ($P = 0.15$). We suggest that the Medina study area had higher estimated nest survival in planted-cover edge because it had 43–63% more planted-cover edge than the other 3 study areas (Table 1), and the fewest number of radiomarked foxes ($n = 5$) and skunks ($n = 17$) compared to the other study areas. The effect is a further dilution of foraging efficiency by predators in planted-cover edge in Medina that contributed to the higher nest success in HGC landscapes.

Despite a consistent selection of planted-cover edges by foxes and skunks, we found no evidence of an edge effect on nest success in planted cover (Horn 2000), which is consistent with observations of waterfowl nest success by Pasitschniak-Arts et al. (1998). Mixed evidence has been found for effects of edge habitat on nesting success. However, many studies indicating increased effects of predation within 50 m of an edge have come from forest–field ecotones (Paton 1994, Andren 1995). The lack of a strong edge effect in prairie ecosystems may be due to vegetation structure along grassland edges similar to core areas and surrounding grain crops during the growing season. Differences in cover-type selection between foxes and skunks illustrate the importance of understanding the potential effect different predator communities have on waterfowl nest success. We observed a greater presence of coyotes (*Canis latrans*) in HGC landscapes than in LGC landscapes. Track survey data collected during our field studies (M. A. Sovada, Northern Prairie Wildlife Research Center, unpublished data) showed that coyote tracks were more frequently found in planted cover and pastureland than in other cover types on our study areas. These track surveys were not detailed enough to assess whether coyotes selected the interior areas of planted cover, but foxes’ avoidance of coyotes may be a factor contributing to the higher nest success of waterfowl in HGC landscapes (Sovada et al. 1995).

Table 4. Daily survival rate (DSR and SE), number of nests ($n$), $\chi^2$ values, and $P$-levels for waterfowl nests in 3 cover types of planted cover and planted-cover types combined for low grassland composition (LGC) and high grassland composition (HGC) landscapes in North Dakota, USA, 1996–1997.

<table>
<thead>
<tr>
<th>Landscape type</th>
<th>Cover type</th>
<th>LGC</th>
<th></th>
<th>HGC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$</td>
<td>DSR</td>
<td>SE</td>
<td>$n$</td>
<td>DSR</td>
</tr>
<tr>
<td>Planted cover–core</td>
<td>302</td>
<td>0.912</td>
<td>0.005</td>
<td>558</td>
<td>0.952</td>
</tr>
<tr>
<td>Planted cover–edge</td>
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<td>0.010</td>
<td>208</td>
<td>0.946</td>
</tr>
<tr>
<td>Planted cover–wetland edge</td>
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<td>0.905</td>
<td>0.008</td>
<td>130</td>
<td>0.942</td>
</tr>
<tr>
<td>Planted cover–core</td>
<td>553</td>
<td>0.909</td>
<td>0.005</td>
<td>896</td>
<td>0.947</td>
</tr>
</tbody>
</table>

Differences in cover-type selection between foxes and skunks illustrate the importance of understanding the potential effect different predator communities have on waterfowl nest success. We observed a greater presence of coyotes (*Canis latrans*) in HGC landscapes than in LGC landscapes. Track survey data collected during our field studies (M. A. Sovada, Northern Prairie Wildlife Research Center, unpublished data) showed that coyote tracks were more frequently found in planted cover and pastureland than in other cover types on our study areas. These track surveys were not detailed enough to assess whether coyotes selected the interior areas of planted cover, but foxes’ avoidance of coyotes may be a factor contributing to the higher nest success of waterfowl in HGC landscapes (Sovada et al. 1995).
MANAGEMENT IMPLICATIONS

Waterfowl nesting cover in the northern Great Plains is being restored through direct grassland acquisition by wildlife agencies and implementation of agricultural policy like the CRP. Management approaches and policy decisions often focus on restoration of waterfowl nesting cover (Reynolds et al. 1994). Our analyses of predator cover-type use will enable wildlife biologists to direct and refine management plans by providing an understanding of the link between predator habitat selection and nest success, and by suggesting new ways to view landscapes from a predator perspective.

Our observations of foxes and skunks provide support for restoration of large blocks of perennial grassland in landscapes that already have a high composition of grasslands, including pastureland. Conversely, the management strategy of restoring small perennial grassland patches in fragmented agricultural landscapes is less likely to increase waterfowl nest success because of the saturated use of these areas by foxes (Greenwood et al. 1995, Sovada et al. 2000). The increased selection of agricultural–wetland edges in both types of landscapes suggests increased selection of perennial grassland along riparian buffer strips that would be established under the buffer initiative of the 1995 Farm Bill. Restoration plans that account for predator response will be more effective in the long term than those that focus only on waterfowl nesting cover.

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