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Small Mammals in Prairie Wetlands: Habitat Use and the Effects of Wetland Modifications

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SMALL MAMMALS IN PRAIRIE WETLANDS:

HABITAT USE AND THE EFFECTS OF WETLAND MODIFICATIONS

BY

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SMALL MAMMALS IN PRAIRIE WETLANDS:

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Masters of Science, and is acceptable for meeting the thesis requirements of this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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G.W.P.

SMALL MAMMALS IN PRAIRIE WETLANDS:

HABITAT USE AND THE EFFECTS OF WETLAND MODIFICATION

Abstract

GREY W. PENDLETON

Although well documented for other habitat types, small mammal habitat use patterns in prairie wetlands are poorly understood. The distribution of the mammal fauna of South Dakota is also not well known. Because of the lack of information in these areas, evaluation of the impacts of wetland modifications on the resident mammal community is not possible. The objectives of this study were (1) to document the species composition and abundance of small mammal communities inhabiting prairie wetland basins, (2) to determine the effects of small scale habitat modification on small mammals, (3) and to explain local species distribution patterns using habitat measurements.

This study was conducted during the summers of 1981 and 1982. Meadow voles (*Microtus pennsylvanicus*) were the most common small mammal in prairie wetlands, followed by deer mice (*Peromyscus* spp.), masked shrews (*Sorex cinereous*), meadow jumping mice (*Zapus hudsonius*) and northern short-tailed shrews (*Blarina brevicauda*). Deer mice were more common in modified habitats within wetland basins than in undisturbed habitat. Modification of wetlands tended to reduce the species diversity of small mammals in the modified areas.

Local distributions of species seemed to be largely determined by soil moisture. Meadow voles used the wettest habitats and deer mice used the driest. Both species of shrew seemed to use habitats intermediate in terms of moisture between wetlands and uplands.

INTRODUCTION

Factors affecting wildlife use of wetlands are poorly understood for most taxa (Weller 1978); this may be particularly true for small mammals. Studies of small mammal distribution and related habitat factors have been conducted in many other habitats. These habitats include forests (Duesser and Shugart 1978, Kirland and Griffin 1974, Miller and Getz 1976), deserts (Price 1978, Rosenweig and Winakur 1969), grasslands (Grant and Morris 1971, Kaufman and Fleharty 1974, M'Closkey and Fieldwick 1975), shelterbelts (Yahner 1982, 1983), and riparian woodlands (Geier and Best 1980). Small mammal communities in wetlands have not received similar attention.

Getz (1961a, 1961b, 1961c) and Ozoga and Verme (1968) recorded small mammal distributions in forested wetlands in Michigan and Coulombe (1965) and Shure (1970) have documented small mammal use of coastal salt marshes. Several habitat studies of individual taxa have included sampling within wetlands (Findley 1951, Spencer and Pettus 1966, Birney et al. 1976). In South Dakota, Wilhelm et al. (1981) recorded small mammal use of habitats, including wetlands, at Lacreek National Wildlife Refuge (Bennett County) in the southwestern part of the state; Lindell (1971) described habitat use patterns of a small mammal community in typical prairie wetlands of eastern South Dakota.

The effects of habitat modification on small mammals have also been documented in many areas. The impacts of clear-cutting (Kirkland

1977), strip-mining (DeCapita and Bookout 1975, Hansen and Warnock 1978), and stream channelization (Geier and Best 1980, Possardt and Dodge 1978) have been investigated. Man-induced modification of wetlands are common throughout the prairie region (Flake 1979). The effects of wetland modificaiton on wildlife in general, and small mammals specifically, are not known.

Small mammals are important components of most terrestrial ecosystems. They are a prey base for a variety of mammalian and avain predators (Johnson and Johnson 1982) and have direct and indirect impacts on faunal and floral community structure (Batzli and Pitelka 1970, Brown 1978, Chew 1978). It has been suggested that small mammals may provide an alternative food source diverting predation from game species. Also, Because of their wide distribution, abundance, and ease of sampling, small mammals may provide a relatively easy method of monitoring wildlife habitat conditions and changes (Armstrong 1977).

The lack of information on the mammal fauna of South Dakota (Choate and Jones 1981) and on small mammals in prairie wetlands, along with the unknown effects of habitat disturbance, makes evaluation of activities that require modification of praire wetlands impossible. The objectives of this study were to document the species composition and abundance of small mammals inhabiting prairie wetlands, to determine the effect of small scale habitat alteration on small mammals, and to explain local species distribution patterns using habitat variables.

STUDY AREAS

Study areas in 1981 comprised 21 semipermanent wetland basins (classification from Stewart and Kantrud 1971) in Marshall, Day, Clark, and Lake counties in eastern South Dakota (Appendix 1). Wetlands were located on U. S. Fish and Wildlife Service Waterfowl Production Areas (WPA) and South Dakota Department of Game, Fish and Parks Game Production Areas (GPA). Eleven wetland basins ("modified basins") contained excavated complexes of ponds and spoil islands ("dug brood complex") primarily constructed to provide open-water waterfowl brood rearing habitat during drought (see Brady 1983, Giron Pendleton 1983). All brood complexes contained standing water; conditions in basins outside of the complex varied from dry to standing water over 0.5 m deep. The 10 unmodified basins were sampled to provide additional species composition and distribution information.

Study wetlands were located on the Coteau des Prairies, a glaciated highland between the Red River and James River lowlands (Westin and Malo 1978). The region contains numerous glacial depression wetlands important to wildlife, notably migratory waterfowl (Brewster et al. 1976). The climate is continental with wide ranges in temperature (Westin and Malo 1978). Land use is predominantly agricultural production including small grains, row crops, and livestock.

Intensive sampling was conducted in 1982 in 2 semipermanent wetland basins, 1 each in Brookings and Moody counties, South Dakota (Appendix 1). Both areas contained standing water but dried during sampling. These sites were located in the same region as those used in 1981.

Two semipermanent wetland basins on the Burke Slough GPA in Miner County, South Dakota were sampled during 1981 and 1982. Two dug brood complexes were constructed within the wetland basins during the winter of 1981-82. Sampling was conducted prior to and following construction. Basins were dry during sampling except brood complexes contained water during 1982. This area is located in the James River lowland (Westin and Malo 1978) and is described by Hubbard (1982) and Pendleton and Davison (1982).

METHODS

Sampling was conducted during 1981 between 1 June and 23 July. Two small mammal trapping transects were established in each study wetland basin. Transects began 15 m (2 trap stations) above the wet meadow zone (Stewart and Kantrud 1971) and extended into the basin. Each transect was 240 m long with 33 trapping stations 7.5 m apart. At least 1 transect intersected the dug brood complex, if present. If the opposite edge of the wetland or open water (standing water without sufficient emergent vegetation to support a trap) were encountered, the transect was continued elsewhere in the marsh where conditions were suitable.

Two Museum Special snap traps were placed at each trap station. Museum Specials have been found to be more efficient than other small mammal traps for a variety of species (Pendleton and Davison 1982, Weiner and Smith 1972). Traps were baited with a mixture of peanut butter and rolled oats and set on the ground where litter had been removed, except where needed to support the trap above standing water. Trapping continued for 4 consecutive days. Traps were examined each morning and baited and reset as needed. Species captured and trap status (sprung with capture, sprung without capture, bait removed, or unsprung) were recorded.

In 1982, trapping was conducted between 20 June and 31 July. Trap stations were arranged in grids on each study wetland basin.

Grids covered essentially all of the basin and some adjacent uplands. Trap stations were located at grid intersections with 10 m spacing in all directions and contained 1 Museum Special trap. The grid on the Brookings County Area (Area 1) was 21 X 20 stations (200 X 190 m) and the grid on the Moody County area (Area 2) was 17 X 17 stations (160 X 160 m).

Traps were prebaited for 4 days prior to initiation of trapping, which continued until a substantial decline occurred in the number of animals captured per day (7 days at Area 1 and 6 days at Area 2). Trapping was conducted in this manner to obtain more accurate population estimates from the removal data (White et al. 1982).

Habitat measurements were recorded at each trapping station on the 1982 study areas. Measurements were taken 1 m from the trap station perpendicular to the grid transect in undistrubed vegetation. Plant height and litter depth were measured with a meter stick. Dead vegetation lying below a 45° angle was considered to be litter. Percent cover by plant taxa (species or genus) was estimated with a 10 X 50 cm quadrat and techniques modified from Daubenmire (1959). Variables generated from species cover data were percent live cover, percent standing dead cover, percent total cover, percent bare soil, and plant species richness. Many wildlife species respond to vegetation structure rather than species composition (Weller 1978, Weller and Spatcher 1965). Plant species at each station were grouped into structural categories to yield percent cover of grasses, forbs, sedges, and robust emergents (*Typha*, *Scirpus*, *Sparganium*). Each station was also classified into a "vegetation zone" (deep marsh, shallow marsh, wet meadow, low prairie, upland, or a transition between zones) based on plant species composition criteria of Stewart and Kantrud (1971).

Other habitat variables included distance from the sampling station to the nearest differing dominant vegetation (an index to habitat patchiness) and percent soil moisture. Soil moisture was measured using 1 soil sample from each station. Samples were weighed to the nearest 0.1 g and oven dried at 80° C to constant weight. Constant weight was considered to be the loss of less than 0.5 g in 48 hours. Percent soil moisture was calculated as the wet weight minus the dry weight, divided by the dry weight and multiplied by 100 (Donahue et al. 1977).

Five trapping transects were used on the Burke Slough GPA both years. Transects were 190 m long and contained 20 trap stations at 10 m intervals. Three transects extended from upland to upland, 1 crossed the wetland and was "doubled-back" into the marsh, and 1 transect began at the upland and ended in the marsh. Trapping was conducted during the second week of August both years.

In 1981, 3 types of traps were used, Museum Special snap traps, Victor-rat snap traps, and Sherman live-traps. Because of greater efficiency, only Museum Special traps were used in 1982. Only data collected with Museum Special traps in 1981 were compared to 1982 data. Trapping was conducted for 5 consecutive days in 1981 and 4 consecutive days in 1982. During the winter of 1981-82, 2 dug brood complexes were constructed within the wetland basins. In 1982, 1 transect extended through each complex with 3 transects as controls.

Catch rates (the number of individuals caught per operable trap night) were calculated for each species at each trap station on all study wetlands. One-half trap night was subtracted for each trap sprung regardless of whether or not a capture was made (Nelson and Clark 1973).

For 1981 data, total catch rates and catch rates by species were compared between sites in modified and unmodified parts of basins using factorial analysis of variance for unbalanced data (Goodnight et al. 1982). Trapping stations within a 2 station distance (15 m) around a dug brood complex were included as "modified" sites.

Small mammal population densities were estmated for the 1982 study areas using methods described by Otis et al. (1978) for removal data. Estimates were calculated using the computer program CAPTURE (see White et al. 1982). This program uses a series of probability models with varying assumptions to estimate population sizes and densities using capture-recapture data from closed poulations. The Zippin model (M(B)) and the generalized removal model (M(BH)) allow the probability of capture to change after the first capture is made (Otis et al. 1978). These models are appropriate for removal sampling where the probability of capture is 0 after the first capture. The generalized removal model also allows subgroups within the population to have differing initial capture probabilities. Density estimates are calculated by the CAPTURE program using nonlinear regression of population estimates on grid areas of nested subgrids (White et al. 1988). The Zippin model was used to estimate population densities in all but one case, where the generalized removal model was appropriate.

Simple correlations were calcuated for each species/habitat variable combination. Associations between the presence or absence of a species and habitat variables were determined using stepwise logistic regression (Engleman 1981). For each trap site, if the catch rate was greater than 0, the species was present and a value of 1 was assigned to that site. If the catch rate was 0 (no individuals of the species were captured), the species was assumed to be absent and a value of 0 was assigned to that site. The dependent variable in the logistic regression was the presence (1) or absence (0) of the species at each trap site. Stepwise logisitic regression fits a logistic curve to the pattern of 0's and 1's based on the independent (habitat) variables entered into the regression equation. Independent variables are entered in a stepwise manner based on the improvement in the log-likelihood ratio and the chi-square goodness-of-fit statistics (Engleman 1981).

For species with sufficient numbers of captures, stepwise discriminant analysis (Jennrich and Sampson 1981) was used to examine differences in habitat use patterns between pairs of species. Results from stepwise procedures should be interpreted cautiously but are acceptable for exploratory research (Johnson 1981a, 1981b). Differences in catch rates among vegetation zones were determined using analysis of variance for unbalanced data (Goodnight et al. 1982) and Fisher's protected least significant different analysis with unequal replications (Steel and Torrie 1980).

Catch rates by species and Shannon-Weiner diversity indicies ($H' = -\Sigma p_i \log p_i$, where p_i is the proportion of total captures in the ith species) were calculated for each of the 5 transects at Burke Slough GPA. Values obtained in 1981 were subtracted from 1982 results to obtain the change between years for each transect. Average changes for modified transects (those transects with dug brood complexes constructed between sampling periods) were compared to the average change from control transects using a Student's t-test for unequal sample sizes (Steel and Torrie 1980).

Inferences from all analyses were made using "tests of significance" rather than "tests of hypotheses" (Kempthorne and Folks 1971). This procedure consists of evaluation of evidence provided by the data rather than accepting or rejecting hypotheses. Interpretations were made based on a "3 decision rule". For each analysis, the probability of getting the calcualted value of the test statistic or more extreme value was computed. If the value was less than approximately 0.05 the alternative hypothesis was concluded to be true. If the probability was between 0.05 and 0.10, a conjecture was made that the alternative was true, while if the probability was greater than 0.10, the null hypothesis was accepted as true.

RESULTS

During 1981, 1084 animals of 11 species were trapped in 8592.5 trap nights (Table 1) for an overall catch rate of 0.1262. Abundant species, the meadow vole (Microtus pennsylvanicus), deer mouse (mostly Peromyscus maniculatus with a few P. leucopus), meadow jumping mouse (Zapus hudsonius), and masked shrew (Sorex cinereous), comprised 94.7% of the captures. Other species caught included thirteen-lined ground squirrel (Spermophilus tridecemlineatus), western harvest mouse (Reithrodontomys megalotis), Gapper's red-backed vole (Clethrionomys gapperi), northern short-tailed shrew (Blarina brevicauda), northern pocket gopher (Thomomys talpoides), and house mouse (Mus musculus). Species order for abundance (the number of individuals of a species caught) was similar to species order for distribution (the number of transects where a species was trapped).

In modified basins, the total catch rate was higher (p=0.0001) for trap sites associated with modification than unmodified sites; the mean catch rate for modified sites was 0.2217 compared to 0.1396 for unmodified sites (Appendix 2). Deer mice were the most commonly caught taxa at modified sites with a catch rate of 0.0939, which was higher (p=0.0001) than the deer mouse catch rate at unmodified sites, 0.0290. Jumping mice were also caught more frequently at modified sites (p=0.015) with a catch rate of 0.0277 compared to 0.0153 for

Table 1. Small mammals trapped at 21 eastern South Dakota study areas during June and July 1981.

Species	Number trapped	Proportion[a]	Number of transects[b]
Meadow vole	521	0.481	42
Deer mouse	239	0.220	33
Meadow jumping mouse	138	0.127	29
Masked shrew	129	0.199	33
Thirteen-lined ground squirrel	34	0.031	19
Western harvest mouse	9	0.008	6
Gapper's red-backed vole	5	0.005	1
Northern short-tailed shrew	4	0.004	3
Northern grasshopper mouse	2	0.002	2
Northern pocket[c] mouse	2	0.002	2
House mouse	1	0.001	1

[a]The proportion of the total number of captures contributed by each species.

[b]42 transects possible.

[c]Range extension - see Pendleton (1983).

unmodified sites. Voles seemed to be captured more often ($p=0.085$) at modified sites compared to unmodified locations, 0.0887 to 0.0747. Of the common species, only masked shrews seemed to be captured less often ($p=0.093$) at modified versus unmodified trap sites, 0.0064 compared to 0.0139.

There were differences ($p<0.005$) in catch rates among study areas for all common species. Also, there were interactions ($p<0.05$) between the effects of area and modification for all taxa except masked shrews.

In 1982, 592 animals of 8 species were captured in 3619.5 trap nights with an overall catch rate of 0.1633 (Table 2). Meadow voles, masked shrews, deer mice, and northern short-tailed shrews were the most common species comprising 91.3% of the individuals caught. Other species trapped were thirteen-lined ground squirrels, meadow jumping mice, a house mouse, and a least weasel (Mustela nivales).

Population densities were estimated for meadow voles, deer mice, and masked shrews on Area 1 and meadow voles and short-tailed shrews on Area 2 (Table 3). Too few data were available for other species to provide reliable estimates. Estimates were made for entire grids. However, since species did not use all habitats within the grid equally, density estimates were also calculated for subsections of the grids if sufficient data were available. Subsections had higher densities and more uniform habitat and probably are a better indication of actual density in the habitats used. Data from several

Table 2. Small mammals trapped at Brookings (Area 1) and Moody (Area 2) county, South Dakota study areas during June and July 1982.

Species	Area 1 Number trapped	Area 1 Proportion[a]	Area 2 Number trapped	Area 2 Proportion
Meadow vole	193	0.479	62	0.325
Masked shrew	96	0.238	28	0.147
Deer mouse	75	0.186	16	0.084
Thirteen-lined ground squirrel	23	0.057	7	0.037
Meadow jumping mouse	11	0.027	10	0.052
Northern short-tailed shrew	5	0.012	66	0.346
House mouse	0	-	1	0.005
Least weasel	0	-	1	0.005

[a]The proportion of the total number of captures contributed by each species.

Table 3. Population densities of selected small mammal species at Brookings (Area 1) and Moody (Area 2) county, South Dakota study areas in 1982.

Species	Overall density (#/ha)	Estimator[a]	Max. Density	Estimator
(Area 1)				
Meadow vole	31.237 (s.e. 1.297)	M(B)	91.290 (s.e. 2.394)	M(B)
Masked shrew	20.630 (s.e. 1.231)	M(B)	-------	
Deer mouse	12.734 (s.e. 5.155)	M(B)	-------	
(Area 2)				
Meadow vole	12.180 (s.e. 0.494)	M(BH)	78.690 (s.e. 6.023)	M(B)
Short-tailed shrew	23.637 (s.e. 3.737)	M(B)	32.445 (s.e. 6.9304)	M(B)

[a]Estimator M(B) follows the Zippin model and estimator M(BH) follows the generalized removal model from Otis et al. (1978).

outer columns of trap stations were deleted when calculating masked shrew density estimates on Area 1 because of non-uniform distribution. The density estimate for deer mice on Area 1 should be interpreted cautiously. More captures were made in the outer rings of the grid compared to the center rings. The result is that the naive density estimates for the subgrids, from which the overall density estimates are calculated, increase from the center of the grid outward, which is opposite from the usual situation. This causes an estimated boundary strip width (White et al. 1982) of zero, which is erroneous and would lead to an overestimate of the density. However, much of the center of the grid had few or no deer mouse captures, which would result in an underestimated density. The extent of these errors is unknown, as are techniques to further refine the estimate.

Meadow voles had the highest population densities with maximums of 91.29 voles/ha on Area 1 and 78.69 voles/ha on Area 2. Short-tailed shrew density on Area 2 had a maximum of 32.45 shrews/ha. For the entire grid on Area 1, masked shrews and deer mice had densities of 20.63/ha and 12.73/ha respectively.

Habitat variables entered into logistic regression equations are interpreted as general indicators of habitat association. The predictive abilities of the regression equations are relatively low and the relationships between habitat variables should not be interpreted as cause and effect (Appendix 3). The direction (sign) of the relationship between a habitat variable and the species catch rate was determined from the simple correlation between the habitat measurements and the catch rates for all sites (Appendix 4). Variables from the regression equations are discussed using signs from the correlation analyses.

The presence of meadow voles was positively related to soil moisture and negatively related to grass cover at both areas (Table 4). The distance to other vegetation types was negatively related to vole presence at Area 1 while at Area 2, vole presence was positively related to the amount of bare soil and plant height.

Deer mouse presence was negatively related to soil moisture and positively related to bare soil at both areas. Deer mouse presence was positively related to grass cover at Area 1 and negatively related to robust emergent cover at Area 2. Total cover was negatively related to deer mouse presence at Area 1 and positively related at Area 2.

The presence of masked shrews was difficult to predict. Robust emergent cover was negatively related to shrew presence at Area 1 and soil moisture was negatively related at Area 2. No other variables entered into the equations.

Habitat relationships for short-tailed shrews were calculated only for Area 2. The presence of short-tailed shrews was positively related to litter depth, forb cover, and sedge cover. The amounts of dead cover and bare soil were negatively related to short-tailed shrew presence. Too few captures were made on other taxa to determine habitat relationships.

Table 4. Relationships between species presence and habitat variables determined by stepwise logistic regression and simple correlation analyses.

Species	Soil moist.	Litter depth	Plant height	Vegetation distance	% bare soil	% total cover	% grass cover	% forb cover	% sedge cover	% emergent cover	% dead cover
(Area 1)											
Meadow vole	+			-			-				
Masked shrew										-	
Deer mouse	-				+	-	+				
(Area 2)											
Meadow vole	+		+		+		-				
Masked shrew	-										
Deer mouse	-	-			+	+				-	
Short-tailed shrew		+			-			+	+		-

Catch rates by species other than short-tailed shrews varied among vegetation zones ($p<0.01$) on both study areas (Appendix 5). Results were similar at both areas (Table 5).

Meadow voles had higher catch rates in the shallow marsh and shallow marsh/deep marsh transition than in other vegetation zones at both study areas. Drier zones had lower catch rates. At both areas, masked shrews were most commonly trapped in the low prairie/wet meadow transition followed by the low prairie zone. Wetter zones had fewer captures. Deer mice were more commonly caught in uplands than in any wetland zone with generally decreasing catch rates as zones became wetter.

Analysis for thirteen-lined ground squirrels was conducted for Area 1 only. Thirteen-lined ground squirrels were most often captured in the low prairie, wet meadow, and the transition between the two with lower catch rates in other zones.

Habitat variables entered into discriminant function equations were interpreted in the same manner as variables in the logistic regression equations (Appendix 6). The sign of a relationship was based on the simple correlation.

At Area 1, meadow vole and deer mouse habitats were best distinguished by the positive associations of voles to soil moisture and sedge cover (Table 6). Deer mice were negatively associated with these variables. Meadow vole habitat was best discriminated from masked shrew habitat based on soil moisture and the distance to other

Table 5. Least significant difference analysis of species catch rates among vegetation zones at 1982 study areas.

<u>Area 1</u>

Species								
Meadow vole	vegetation zone:[a]	0	1	2	3	4	5	6
	mean catch rate:	0.0578	0.0603	0.0701	0.0341	0.1002	0.1313	0.1474
							A	A
				B		B		
		C[b]	C		C			
Masked shrew	vegetation zone:	0	1	2	3	4	5	6
	mean catch rate:	0.0581	0.0693	0.0983	0.0569	0.0346	0.0285	0.0000
				A				
		B	B		B			
						C	C	
							D	D
Deer mouse	vegetation zone:	0	1	2	3	4	5	6
	mean catch rate:	0.1451	0.0552	0.0393	0.0654	0.0065	0.0016	0.0165
		A						
			B	B	B			
				C				C
						D	D	D

Table 5. continued

Thirteen-lined ground squirrel	vegetation zone:	0	1	2	3	4	5	6	
	mean catch rate:	0.0036	0.0289	0.0239	0.0280	0.0017	0.0023	0.0000	
			A	A	A				
		B				B	B	B	

Area 2

Species

Meadow vole	vegetation zone:	0	1	2	3	4	5	6	7
	mean catch rate:	0.0142	0.0318	0.0267	0.0000	0.0393	0.0856	0.0908	0.0694
							A	A	A
						B			B
		C	C	C		C			
		D	D	D	D				
Masked shrew	vegetation zone:	0	1	2	3	4	5	6	7
	mean catch rate:	0.0219	0.0398	0.0859	0.0123	0.0106	0.0028	0.0214	0.0091
				A					
			B						
		C			C			C	
					D	D	D		D

Table 5. continued

Deer mouse	vegetation zone:	0	1	2	3	4	5	6	7
	mean catch rate:	0.0571	0.0159	0.0166	0.000	0.0000	0.0000	0.0000	0.0000
		A							
			B	B	B	B	B	B	B

[a]vegetation zones: 0=upland, 1=low prairie, 2=low prairie/wet meadow, 3=wet meadow, 4=wet meadow/shallow marsh, 5=shallow marsh, 6= shallow marsh/deep marsh, 7=deep marsh.

[b]Zones underscored by the same letter are not different ($p<0.05$).

Table 6. Habitat variables from discriminant function and simple correlation analyses used to distinguish habitats of pairs of species from 1982 study areas.

Area 1

	Soil moisture	% sedge cover
Meadow vole	+	-
vs		
Deer mouse	-	+

	Soil moisture	Vegetation distance
Meadow vole	+	-
vs		
Masked shrew	-	+

	% total cover	% grass cover
Masked shrew	-	+
vs		
Deer mouse	-	+

Area 2

	Soil moisture	%forb cover	% sedge cover
Meadow vole	+	-	-
vs			
Short-tailed shrew	-	+	+

	% sedge cover
Masked shrew	-
vs	
Short-tailed shrew	+

vegetation types ("habitat patchiness"). Voles were positively related to vegetation distance. Deer mouse habitat and masked shrew habitat were similar. The best discriminating variables were total cover and grass cover. Both were negatively associated with total cover and positively associated with grass cover, however the relationships were stronger for deer mice than for masked shrews.

At Area 2, habitat comparisons were made between meadow voles and short-tailed shrews and between short-tailed and masked shrews. Meadow vole habitat and short-tailed shrew habitat were best separated by soil moisture, forb cover, and sedge cover. Voles were positively associated with soil moisture and negatively associated with forb cover and sedge cover, while short-tailed shrews had the opposite relationships. The only variable entered to separate short-tailed shrew habitat from masked shrew habitat was sedge cover. Short-tailed shrews were positively associated with sedge cover while masked shrews were negatively associated with sedge cover.

In combined results from 2 years sampling at Burke Slough GPA, 154 individuals of 7 species were caught (Table 7). Deer mice and meadow voles made up 72.1% of the captures followed by western harvest mice, meadow jumping mice, northern short-tailed shrews, and masked shrews.

Between 1981 and 1982, species diversity (H') on transects that had been modified in the winter of 1981-82 declined in relation to diversity on control transects (t=5.123, 3df, p=0.007). The catch

Table 7. Small mammals trapped at Burke Slough GPA during August 1981 and 1982.

Species	Number trapped[a]		Proportion[b]	Number of transects[c]
Deer mouse	1981:	22	0.361	4
	1982:	39	0.419	5
	total:	61	0.396	
Meadow vole	1981:	15	0.246	4
	1982:	35	0.376	4
	total:	50	0.325	
Meadow jumping mouse	1981:	7	0.115	1
	1982:	6	0.065	3
	total:	13	0.084	
Western harvest mouse	1981:	8	0.131	3
	1982:	5	0.054	3
	total:	13	0.084	
Northern short-tailed shrew	1981:	1	0.016	1
	1982:	8	0.086	3
	total:	9	0.058	
Masked shrew	1981:	5	0.082	4
	1982:	0	0.000	0
	total:	5	0.032	
Thirteen-lined ground squirrel	1981:	3	0.049	2
	1982:	0	0.000	0
	total:	3	0.019	

[a]The numbers of traps used and trap nights differed between years.

[b]The proportion of the total number of captures contributed by each species.

[c]5 transects possible

rate for meadow voles also declined on modified transects in relation to control transects from 1981 to 1982 ($t=2.251$, 3df, $p=0.055$). Changes between years in total catch rates and for other species were not different between modified and unmodified transects.

DISCUSSION

Taxa trapped in this study are representative of the small mammal assemblage of the northern Great Plains (Jones et al. 1983). All of the taxa caught in wetlands have also been found in upland habitats in the region (Barnes and Linder 1982, Searles 1974, Yahner 1982), and all were within documented ranges except the northern pocket gopher (Pendleton 1983).

Habitat Relationships

Meadow voles are usually associated with grassland habitats (Johnson and Johnson 1982, Reich 1981) and have been shown to prefer grassland rather than woodland (Getz 1961b, Grant 1971, M'Closkey and Fieldwick 1975, Wrigley 1974, Yahner 1982, 1983). Voles have also been reported to use hydric and mesic habitats rather than more xeric habitats (Findley 1951, Getz 1961b, 1970, Wrigley 1974) and areas with dense grass cover more than areas with sparse cover (Douglass 1976, Hodgson 1972). Birney et al. (1976) reported higher meadow vole population densities in a grass-sedge wetland than in upland grassland in the same region. Studies of meadow vole habitat use of "hydric grasslands", such as prairie wetlands, have been uncommon (Lindell 1971).

In this study, meadow voles were positively associated with soil moisture. Also, vole catch rates were higher in wetter vegetation zones than in dryer zones. Other studies of vole habitat generally have not included shallow marsh and deep marsh habitats but still indicate that voles select the wettest sites available (Birney et al. 1976, Getz 1970). Hodgson (1972) found meadow voles to be positively related to grass cover and total cover and Geier and Best (1980) reported voles to be positively related to forb cover. In this study, voles were negatively related to grass cover at both study areas. At each of these areas, upland sites were dominated by grasses while fewer wetland sites had substantial grass cover. Seemingly, grass cover per se is not a limiting factor in meadow vole distribution if other food sources are available and other habitat factors affect habitat selection more than vegetation composition.

Masked shrews have been recorded in a variety of wooded and non-wooded habitats (Iverson et al. 1967, Wrigley et al. 1979, Yahner 1982) but seem to be most abundant in relatively moist habitats (Brown 1967a, Buckner 1966, Clark 1973, Getz 1961a, Spencer and Pettus 1966, Wrigley 1974, Wrigley et al. 1979). Habitats dominated by sedges and rushes (wet meadow to shallow marsh zones and their transition based on Stewart and Kantrud 1971) have been reported as preferred habitats (Clark 1973, Spencer and Pettus 1966, Wrigley et al. 1979).

In this study, masked shrew habitat was difficult to predict. This difficulty may be because shrews used habitat where the values of habitat variables were near the mean, resulting in these variables not being entered into stepwise regression and discriminant function equations (see Johnson 1981a). The presence of masked shrews was negatively associated with robust emergent cover and soil moisture. These results seem to contradict earlier studies. Masked shrews had the highest catch rates in the low prairie/wet meadow transition. So, masked shrews were using habitats intermediate in terms of moisture. Masked shrews did not use the wettest habitats available, as did meadow voles, and did not use dry habitats as much as deer mice, but used the transition area between wetland and upland habitats.

Deer mice are found in a wide variety of habitats (Baker 1968, Jones et al. 1983) and they are the most common small mammal in many areas (Wilhelm et al. 1981). Though they are usually more common in drier upland habitats (Brown 1967b, Kaufman and Fleharty 1974), deer mice also use wetland edges (especially *P. Leucopus*) (Wilhelm et al. 1981). Geier and Best (1980) found *P. maniculatus* to be positively associated with forb cover and negatively related to plant species richness; *P. leucopus,* which used more wooded habitat, was positvely related to grass cover.

In this study, deer mice were negatively related to soil moisture, total cover, and robust emergent cover, and positively associated with grass cover and the amount of bare soil. These relationships agree with the findings of Wilhelm et al. (1981) who stated that deer mice used "upland habitats with moderate cover" and Baker (1968) who reported that deer mice were usually found in open habitats and pioneer grasslands. Lindell (1971) found deer mice most abundant in habitat dominated by cattail (*Typha* spp.) and bulrush (*Scirpus* spp.), which is opposite from the results of this study. Deer mice were more abundant in uplands than in any wetland habitat, although they seemingly invaded wetlands under some conditions.

Short-tailed shrews are found in many different habitats (Getz 1961a, Jones et al. 1983, Wrigley et al. 1979, Yahner 1982). Getz (1961a) reported that short-tailed shrew abundance was not related to cover but that shrews avoided dry habitats and areas inundated with water. Short-tailed shrews are usually most abundant in moist habitats, especially grass-sedge meadows (Getz 1961a, Wrigley et al. 1979). Geier and Best (1980) found that short-tailed shrews were positively associated with grass cover and brushpiles. Lindell (1971) found short-tailed shrews most abundant in grass dominated with deep litter. These findings agree closely with the results of this study where short-tailed shrews were most often found in transition wetland/upland habitats often dominated by sedges and forbs with deep litter layers. They used drier habitats than meadow voles but habitats similar to those used by masked shrews.

Effects of Modification

Small scale modification of prairie wetlands (i.e. dugouts and dug brood complexes) resulted in a lower diversity of small mammals on the modified sites compared to unmodified parts of the basin. Also, some species were caught more frequently at modified sites than unmodified sites while other species were caught less often on modifications. Several factors, including the abundance of each species prior to modification, the location of modifications within the basins, and the length of time since modification may all affect the abundance of a species on a modified site. Meadow voles were caught at least as frequently on modified sites as on unmodified sites at 1981 study areas. But, at Burke Slough, meadow vole abundance declined on modified sites the year after modification. In 1981, "modified sites" included locations immediately surrounding actual modifications that were not physically disturbed. These sites may have retained meadow voles already present or, voles may have been attracted to the standing water provided by the modifications during 1981 (a drought year).

The same may also be true for meadow jumping mice, which were captured more frequently at modified than at unmodified sites. Several studies have found jumping mice to be most abundant in wet habitats (Quimby 1951, Shure 1970, Whitaker 1979) and they may also be attracted to standing water (Getz 1961c). Jumping mice at modified sites may be "remnants" from the area prior to modification or they may be attracted to the standing water. Possardt and Dodge (1978) found jumping mice less abundant in disturbed habitat possibly because of a loss of vegetative cover (Quimby 1951).

Masked shrews seemed to be less abundant on modified sites compared to unmodifed sites. Masked shrews are an "edge" species and not as common in the central parts of wetland basins. However, the lack of surface cover on disturbed sites may have resulted in avoidance of these areas by masked shrews. Masked shrews were the only species whose catch rates between modified and unmodified sites were not affected by the area (no interaciton between area and modifications). Possardt and Dodge (1978) also found masked shrews less common in disturbed habitats.

Deer mice are a species of relatively open habitats (Baker 1968) and are known to pioneer into disturbed areas (DeCapita and Bookout 1975, Hansen and Warnock 1978, Wrigley 1974). Deer mice were more common at modified sites than at unmodified sites in this study confirming these other results. At Burke Slough, deer mice comprised 84% of the captures on modified sites the year after modification. Deer mice were associated with drier sites and bare soil, which would account for their use of the relatively dry and open soil banks of the modifications.

General Comments

The distributions of small mammals in and around prairie wetlands seems to be a continuum based largely on soil moisture. Meadow voles occupy the moist wetland habitats and deer mice the drier surrounding uplands. Masked shrews are found in transition habitats intermediate in moisture between uplands and wetlands. Short-tailed shrews, although difficult to classify, seem to use transition habitats similar to masked shrews. Although limited data is availble on other species, meadow jumping mice seemed to use moist habitat similar to meadow vole habitat and thirteen-lined ground squirrels used upland habitats similar to deer mice.

Local abundance and species combinations varied widely among outwardly similar wetlands. Much of this study was conducted during a drought period and many wetlands were dry during trapping sessions (especially in 1981). Under dry conditions, upland wildlife species often use wetlands (Schitoskey and Linder 1978, Weller and Spatcher 1965). This use undoubtedly occurs with small mammals and would affect the composition of the community at any specific time and place. Meadow voles have been shown to be tolerant of flooding (Fisler 1961), which may partially account for vole dominance in wetland habitats. The pioneering tendencies of deer mice would account for their abundance in dry wetland habitats found by Lindell (1971) and their abundance on spoil islands ("artificial uplands") created by wetland modification.

The effect of small scale modification of prairie wetland basins on small mammal communities would be difficult to predict for a specific site because of interactions among local community composition and available habitats. However, at modified sites in general, an increase in deer mouse populations and a decrease in other species and diversity could probably be expected.

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Appendix 1: Location of eastern South Dakota study areas used during 1981 and 1982.

1981

Clark County

Kueker WPA*	T 119N, R 57W, sec. 1
Lynbye GPA	T 119N, R 57W, sec. 10
Bender WPA	T 119N, R 57W, sec. 35
Graves WPA*	T 118N, R 57W, sec. 29 (2 wetland basins used)
Austin WPA*	T 117N, R 57W, sec. 4
Storebeck WPA*	T 117N, R 46W, sec. 10
Stairs Slough GPA	T 115N, R 57W. sec. 8
Anderson WPA*	T 115N, R 57W, sec. 28

Day County

Hedman GPA*	T 124N, R 57W, sec. 15
Dolney WPA	T 124N, R 56W, sec. 18
Strangeland WPA*	T 124N, R 56W, sec. 30
Schmig WPA*	T 121N, $ 572, sec. 12
Kriesch WPA	T 122N, R 56W, sec. 9 (2 wetland basins used)

Lake County

Krug WPA	T 108N, R 54W, sec. 24
Glatz WPA*	T 106N, R 54W, sec. 17
Pearson WPA*	T 105N, R 54W, sec. 21

Marshall County

Fort Section GPA*	T 126N, R 56W, sec. 10 (2 wetland basins used)
Deutsch WPA	T 125N, R 55W, sec. 20

1982

Brookings County

Pittenger WPA	T 111N, R 51W, sec. 28

Moody County

Anderson WPA	T 107N, R 50W, sec. 5

Appendix 1. continued

<u>1981 & 1982</u>

Miner County

Burke Slough GPA* T 106N, R 57W, sec. 21

*Contains a dug brood complex

Appendix 2. Analysis of variance of total and species catch rates between modified and unmodified trap sites.

	Source of variation	Degrees of freedom	Mean square	F-value	P-value
Total catch	TRT: modification	1	1.5284	42.80	0.0001
	Area	10	0.2460	6.89	0.0001
	TRT X area	10	0.0775	2.17	0.0178
	Error	704	0.0357		
Meadow vole	TRT: modification	1	0.0520	2.97	0.0851
	Area	10	0.1608	9.19	0.0001
	TRT X area	10	0.0478	2.73	0.0026
	Error	704	0.0175		
Deer mouse	TRT: modification	1	0.8395	72.59	0.0001
	Area	10	0.0570	4.93	0.0001
	TRT X area	10	0.0637	5.51	0.0001
	Error	404	0.0116		
Masked Shrew	TRT: modification	1	0.0069	2.83	0.0932
	Area	10	0.0054	2.19	0.0169
	TRT X area	10	0.0024	0.96	0.4802
	Error	704	0.0025		
Meadow jumping mouse	TRT: modification	1	0.0362	5.96	0.0149
	Area	10	0.0283	4.66	0.0001
	TRT X area	10	0.0156	2.58	0.0045
	Error	704	0.0061		

Appendix 3. Stepwise logistic regression results for the presence or absence of each species based on habitat variables.

Area 1

Dependent variable	Independent variable	Chi-square improvement	P-value	Goodness of fit Chi-square	Goodness of fit P-value
	Intercept			540.880	0.000
Meadow vole	Soil moisture	31.012	0.000	509.867	0.000
	Vegetation dist.	4.661	0.031	505.206	0.000
	% grass cover	4.454	0.035	500.752	0.001
	(Approximate correct classification: 65%)				
	Intercept			411.725	0.412
Masked shrew	% emergent cover	18.804	0.000	392.920	0.657
	(Approximate correct classification: 60%)				
	Intercept			322.271	0.999
Deer mouse	Soil moisture	42.409	0.000	279.962	1.000
	% bare soil	7.124	0.008	272.838	1.000
	% grass cover	5.446	0.020	267.393	1.000
	% total cover	9.441	0.002	257.982	1.000
	(Approximate correct classification: 75%)				

Appendix 3. continued

Area 2

Dependent variable	Independent variable	Chi-square improvement	P-value	Goodness of fit Chi-square	Goodness of fit P-value
	Intercept			280.225	0.468
Meadow vole	Soil moisture	27.152	0.000	253.074	0.856
	% grass cover	6.445	0.011	246.629	0.905
	% bare soil	4.096	0.043	242.533	0.928
	Plant height	3.032	0.082	239.500	0.940
	(Approximate correct classification: 70%)				
	Intercept			173.095	1.000
Masked shrew	Soil moisture	5.606	0.018	167.489	1.000
	(Approximate correct classification: 60%)				
	Intercept			99.075	1.000
Deer mouse	Soil moisture	21.565	0.000	77.511	1.000
	% bare soil	3.312	0.069	74.199	1.000
	% total cover	3.770	0.052	70.429	1.000
	% emergent cover	3.873	0.049	66.556	1.000
	Litter depth	2.347	0.126	----	
	(Approximate correct classification: 77.5%)				

Appendix 3. continued

Dependent variable	Independent variable	Chi-square improvement	P-value	Goodness of fit Chi-square	P-value
	Intercept			285.682	0.379
Short-tailed shrew	Litter depth	11.973	0.001	273.709	0.561
	% forb cover	9.218	0.002	264.491	0.695
	% sedge cover	4.492	0.034	259.998	0.747
	% dead cover	4.399	0.036	255.599	0.794
	% bare soil	9.623	0.002	245.976	0.887
	(Approximate correct classification: 67.5%)				

Appendix 4. Simple correlations between species catch rates and habitat variables.

Area 1

Variable	Meadow vole	Masked shrew	Deer mouse	Thirteen-lined ground squirrel
Soil moisture	0.1954	-0.2003	-0.2915	-0.1332
% bare soil	-0.0032	-0.0454	0.1547	0.0055
Litter depth	0.0308	0.0307	-0.1463	-0.0557
Plant height	0.1741	-0.1765	-0.2939	-0.1638
Vegetation dist.	-0.0738	0.1610	0.0872	0.0180
Plant spp.	0.0376	0.0005	-0.1386	-0.0107
% live cover	0.0039	-0.0536	-0.1972	-0.0656
% dead cover	0.0629	-0.0385	-0.1285	0.0580
% total cover	0.0285	-0.0576	-0.2119	-0.0336
% grass cover	-0.1961	0.1596	0.2088	0.1618
% forb cover	0.0646	-0.0478	-0.1982	-0.1057
% sedge cover	0.0851	-0.0471	-0.1875	-0.0830
% emergent cover	0.1700	-0.1931	-0.1707	-0.1107

Area 2

Variable	Meadow vole	Masked shrew	Deer mouse	Short-tailed shrew
Soil moisture	0.2789	-0.1422	-0.2245	-0.0643
% bare soil	0.2316	-0.0940	0.0893	-0.1458
Litter depth	-0.0378	-0.0253	-0.8743	0.1743
Plant height	0.1859	-0.1244	-0.1236	-0.1049
Vegetation dist.	-0.1333	0.0849	0.1243	-0.0111
Plant spp.	-0.0009	0.1235	-0.0351	-0.0472
% live cover	-0.1138	0.0717	-0.0063	0.1295
% dead cover	0.0278	0.0571	0.0498	-0.1117
% total cover	-0.0856	0.0981	0.0247	-0.0487
% grass cover	-0.0049	0.0996	0.1294	-0.0854
% forb cover	-0.1310	0.0805	0.0696	0.1508
% sedge cover	-0.0246	-0.0675	-0.1414	-0.1399
% emergent cover	0.1047	-0.0510	-0.0982	-0.1422

Appendix 5. Analysis of variance of species catch rates among vegetation zones at 1982 study areas.

	Source of variation	Degrees of freedom	Mean square	F-value	P-value
Area 1					
Meadow vole	TRT: veg. zone	6	0.0618	3.15	0.0031
	Error	401	0.0196		
Masked shrew	TRT: veg. zone	6	0.0279	2.70	0.0096
	Error	401	0.0103		
Deer mouse	TRT: veg. zone	6	0.0078	13.00	0.0010
	Error	401	0.0102		
Thirteen-lined ground squirrel	TRT: veg zone	6	0.0078	3.59	0.0010
	Error	401	0.0022		
Area 2					
Meadow vole	TRT: veg. zone	7	0.0417	3.17	0.0032
	Error	272	0.0132		
Masked shrew	TRT: veg. zone	7	0.0202	3.81	0.0006
	Error	272	0.0053		
Deer mouse	TRT: veg. zone	7	0.0158	3.36	0.0020
	Error	272	0.0047		
Short-tailed shrew	TRT: veg. zone	7	0.0179	1.69	0.1107
	Error	272	0.0106		

Appendix 6. Results of stepwise discriminant analysis between pairs of speciesbased on habitat variables.

Area 1

Contrast	No. of cases	% correclty classified	Discriminant variables (and approx. F-statistic)	Within group means	
Meadow vole	129	74.4		M. vole	M. shrew
vs			Soil moisture (35.218)	52.44	35.18
Masked shrew	56	71.4	Vegetation distance (21.405)	7.46	11.64
Meadow vole	149	74.5		M. vole	D. mouse
vs			Soil moisture (66.223)	50.78	27.15
Deer mouse	49	83.7	% sedge cover (36.836)	11.12	1.73
Masked shrew	72	54.2		M. shrew	D. mouse
vs			% total cover (11.513)	52.71	43.41
Deer mouse	44	77.3	% grass cover (9.375)	26.85	33.02

Appendix 6. continued

Area 2

Contrast	No. of cases	% correclty classified	Discriminant variables (and approx. F-statistic)	Within group means	
Meadow vole	53	71.7		M. vole	S.t. shrew
vs			Soil moisture (22.097)	55.85	41.06
Short-tailed shrew	55	78.2	% sedge cover (20.065)	15.72	23.42
			% forb cover (17.032)	4.02	11.98
			Plant spp. richness	2.77	2.91
Masked shrew	23	69.6		M. shrew	S.t. shrew
vs			% sedge cover (7.504)	9.96	23.96
Short-tailed shrew	55	52.7			