12-1984

Small Mammal Populations and Rodent Damage in Nebraska No-Tillage Crop Fields

Kent E. Holm
University of Nebraska-Lincoln

Kent E. Holm

Dept. of Forestry, Fisheries
and Wildlife
202 Natural Resources Hall
University of Nebraska
Lincoln, NE 68583-0819

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by

Kent E. Holm

A THESIS

Presented to the Faculty of

The Graduate College in the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Forestry, Fisheries and Wildlife

Under the Supervision of Professor Ron J. Johnson

Lincoln, Nebraska

December, 1984

ABSTRACT

Small mammal populations were evaluated during 1983 and 1984 in 23 no-tillage cornfields in western (Red Willow County) and eastern (Saline and Jefferson Counties) Nebraska. In 1983, small mammals were trapped during 3 periods (post emergence, maximum corn height, and post harvest), and in 1984, during the post emergence period only. Small mammal captures totaled 1089 (14.6 captures per 100 trap nights overall). Deer mice, Peromyscus maniculatus, were the most abundant species, comprising more than 80% of all captures. Other species captured included white-footed mice (Peromyscus leucopus), northern grasshopper mice (Onychomys leucogaster), thirteen-lined ground squirrels (Spermophilus tridecemlineatus), hispid pocket mice (Perognathus hispidus), Ord's kangaroo rats (Dipodomys ordii), western harvest mice (Reithrodontomys megalotis), voles (Microtus sp.), house mice (Mus musculus), and short-tailed shrews (Blarina brevicauda). Deer mice were captured throughout study fields. Kangaroo rats and voles were always captured near field borders. Other species showed no clear distribution patterns, partly because of the small number of captures. In 1983, average rodent damage to newly planted corn was 8.3% (range: 5.0-10.3%) for western fields and 4.7% (range: 0.3-10.5%) for eastern fields. Damage by rodents in 1984 was less than 1% in eight of the 11 fields studied. Western fields averaged

1.5% damage (range: 0.4-2.1%) while eastern fields had only 0.02% damage (range: 0-0.08%). Food habits analysis indicated that five rodent species consumed corn during the post emergence period and therefore were implicated in causing some of the damage to newly planted corn. Insects, some of which feed on corn seeds and/or seedlings, were present in the stomach contents of seven of the nine species analyzed. Evaluating the beneficial and harmful food habits as well as other life habits of small mammals will enhance the evaluation and predictability of damage control methods.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the assistance of numerous individuals. Cooperation of the Cooperative Extension Service, UN-L, Institute of Agriculture and Natural Resources (IANR), in obtaining study sites and for initial contacts with private landowners is greatly appreciated. Randy Pryor, Saline County Extension Agent, and Bob Rathjen and Robert Klein, Red Willow County Extension Agents, were particularly helpful in obtaining study fields. I extend my sincere appreciation to the following landowners for allowing me to conduct this study in their no-till cornfields: L. Brooks, D. Ebbers, H. Huffman, E. Kleine, E. Moore, P. Schaffert, and W. Schoenbeck. Partial funding for this project was provided by the North Central Regional Pesticide Impact Assessment Program (NCR-PIAP).

I thank my major advisor, Dr. Ron J. Johnson, for initiating the study and for providing needed guidance, advice, and constructive criticism. Thanks also to the other two members of my graduate committee, Dr. Ron Case, Forestry, Fisheries and Wildlife, and Dr. Dave Keith, Department of Entomology for assistance with trapping techniques and insect/arthropod considerations, respectively, as well as constructive criticism and other helpful advice and encouragement.

Tom Labedz, Nile Kimble, and Tom Christiansen assisted with field and laboratory work; their hard work is greatly appreciated. Thanks to graduate students Larry Angle, Jeremy Cable, Pat Cole, Daryl Fisher, Scott Glup, Pat Hegarty, and Ann Koehler, members of the Forestry, Fisheries and Wildlife Graduate Seminar, and faculty members Ed Peters, Bob Timm, and Howard Wiegers for advice and encouragement. Thanks to Jeanne Andelt for typing manuscripts and answering my numerous procedural questions.

Dr. Walt Stroup, Biometrics and Information Systems Center, assisted with experimental design and data analyses; his inputs were valuable and greatly appreciated. Dr. Ackland Jones, Department of Entomology, helped identify insect fragments in the rodent stomachs and was gracious enough to allow me to attend his Introductory Entomology lab. Dr. Patricia Freeman, curator of the vertebrate museum, assisted with the identification of some of the small mammals. Dr. Thomas Silletto, Department of Agricultural Engineering, helped design and construct a core sampler for the surface residue analysis.

A special thanks to my wife, Bobbi, for advice, assistance with lab work, editing of manuscripts, and much needed moral support.

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LITERATURE REVIEW

Use of conservation tillage farming systems has increased markedly in recent years, a trend expected to continue (USDA 1975). The Conservation Tillage Information Center (Conserv. Tillage Inf. Cent. 1984) defines conservation tillage as:

> "...any tillage and planting system that retains at least 30 percent residue cover on the soil surface after planting. Conservation tillage includes no-till ... and other tillage and planting systems that meet the 30 percent surface residue requirement. Residue cover may be from meadow, winter cover crop, small grain, or row crops... Weeds are controlled primarily by herbicides."

Wildlife species, especially ground nesting birds, reportedly increase under conservation tillage conditions, particularly no-till (Fenster and Wicks 1977, Nason 1981) which leaves at least 90% of crop residues on the soil surface (Conserv. Tillage Inf. Cent. 1984). This increased residue cover provides nesting sites for species such as pheasants, meadowlarks (Sturnella spp.), mourning doves (Zenaida macroura), and horned larks (Eremophila alpestris) (Nason 1981, K.Holm et al. 1984). Populations of small mammals are reported to thrive under conservation tillage conditions (Johnson et al. 1982). The crop residues left on the soil surface apparently provide improved small mammal habitat while the lack of tillage allows rodents to establish burrow systems (Johnson et al. 1982, Rodgers and Wooley 1983).

In an Iowa study, Young and Clark (1984) found more small mammal species on minimum-till fields than on disced fields (conventionally-tilled), although the total number of small mammals was generally greater in disced fields. Deer mice were the most abundant species captured (71% of all captures). White-footed mice, western harvest mice, house mice, northern grasshopper mice, meadow voles (Microtus pennsylvanicus), thirteen-lined ground squirrels, short-tailed shrews, and masked shrews (Sorex cinereus) were also captured.

One might expect that where little if any vegetative cover is present and the soil is disturbed regularly, as would be the case in conventionally-tilled fields, that small mammals would be relatively rare. However, Fleharty and Navo (1983) found nine different small mammal species in conventionally-tilled, center pivot irrigated cornfields in Kansas. In a similar study in conventionally-tilled wheat and grain sorghum fields, Navo and Fleharty (1984) captured 11 small mammal species. Houtcooper (1978) found, in decreasing order of abundance, deer mice, house mice, white-footed mice, short-tailed shrews, meadow voles, prairie voles (Microtus ochrogaster), jumping mice (Zapus hudsonius), Norway rats (Rattus norvegicus), and thirteen-lined ground squirrels in Indiana conventionally-tilled corn and soybean fields. Johnson (1926) and Wood (1910) also reported capturing deer mice throughout cultivated fields. Hence it is apparent that small mammals inhabit both conventional and conservation-tillage fields.

Some species of rodents damage newly-planted corn and other crops by digging and consuming the planted seeds and the kernels attached to seedlings (Johnson et al. 1982). Young and Clark (1984) found an average of only 1% damage attributable to rodents in Iowa cornfields, whereas Beasley and McKibben (1976) found damage exceeding 50% in some of their experimental plots in Illinois. Species reported as possibly causing damage include kangaroo rats, voles, deer mice, house mice, and bog lemmings (Synaptomys cooperi) (Johnson et al. 1982). However, thirteen-lined ground squirrels are most often cited as causing damage to newly planted corn (Stoner 1918, Fitzpatrick 1925, Hisaw and Emery 1927, Nason 1981, Johnson et al. 1982).

Despite the damage that some of these rodents cause, the damage susceptible period of the crop is relatively short, generally not more than 3 weeks after corn planting. Furthermore, many of these rodents have food habits that are generally beneficial (Hansen 1975, Beasley and McKibben 1976, Houtcooper 1978, Schwartz and Schwartz 1981, Zimmerman 1965). They consume insects that cause damage to crops and may thereby reduce insect damage. For example, thirteen-lined ground squirrels consume an average of about 50% plant material and 50% animal foods (Flake 1973, Schwartz and Schwartz 1981). Early food habits studies by

Orcutt and Aldrich (1892), Bailey (1893), Stoner (1918), and Fitzpatrick (1925) documented the ground squirrel's omnivorus diet and the beneficial aspect of their consumption of crop-damaging insects such as cutworms. Deer mice, the most common species found in Iowa corn fields (Young and Clark 1984), are also omnivorous and tend to utilize foods that are readily available (Houtcooper 1978). Lepidoptera larvae were important foods of deer mice in the corn and soybean fields that Houtcooper (1978) examined. In a similar study, Whitaker (1966) also found lepidoptera larvae to be the most important food of P. maniculatus; cultivated crops also made up a substantial portion of the diet. Northern grasshopper mice consume a large proportion of animal material (Horner et al. 1965). Food habits studies by Bailey and Sperry (1929) indicated that animal foods made up 89% of the diet, and of this, 79% was insect material. Hansen (1975), studying the food habits of 136 grasshopper mice, found that arthropods made up 87% of the diet, and nearly all of these were types that feed on plants (eg. adult grasshoppers and larval beetles and Lepidoptera). Bailey and Sperry (1929) reported Orthoptera, Coleoptera, and Lepidoptera as the most common insect orders in the diet of the grasshopper mouse. They also state that in favorable habitats this mouse may become quite numerous and exert a controlling influence on the abundance of arthropods and other small mammals. Schwartz and Schwartz (1981) state that shrews (Blarina spp. and Sorex spp.) consume predominantly animal foods, including insects, other arthropods, and some vertebrates. Kangaroo rats are granivores that eat large amounts of seeds, and leaves of grasses, forbs, and shrubs, but also consume some arthropods (Flake 1973).

In addition to insect consumption, small mammals also feed on weed seeds and waste grain (Whitaker 1966, 1972, Zimmerman 1965). Beasley and McKibben (1976) state that certain species of mice and voles occurring in no-tillage fields consume weeds which compete with corn. Grain, left on the soil surface after harvest operations, is also consumed by rodents, reducing the potential for volunteer crops during the next growing season. Pocket mice are primarily granivores and consume grain (especially wheat) remaining after harvest operations (Scheffer 1938).

SMALL MAMMAL POPULATIONS AND RODENT DAMAGE IN NEBRASKA NO-TILLAGE CORNFIELDS

INTRODUCTION

Some species of small rodents cause damage to planted corn and other grain crops by digging and consuming the newly planted seeds and kernels attached to seedlings (Johnson et al. 1982, Koehler 1983). Awareness of this problem has become more acute in recent years (B. Holm et al. 1984) with the increased use of conservation tillage farming systems (USDA 1975).

Conservation tillage is defined as "...any tillage and planting system that retains at least 30 percent residue cover on the soil surface after planting... Residue cover may be from meadow, winter cover crop, small grain, or row crops." (Conserv. Tillage Inf. Cent. 1984). One form of conservation tillage, no-till, leaves at least 90% of the crop residues on the soil surface and, except for the planting operation, does not disturb the soil (Conserv. Tillage Inf. Cent. 1984). No-till benefits wildlife such as ground nesting birds by providing nesting habitat (Nason 1981). Small mammals also thrive (Johnson et al. 1982) and reportedly increase in numbers under no-till conditions (Timm 1980, Nason 1981). The crop residues left on the soil surface apparently provide improved habitat while the lack of tillage allows for establishment of rodent burrow systems (Johnson et al. 1982, Rodgers and Wooley 1983).

Recently, Young and Clark (1984) compared small mammals in conventional and conservation tillage cornfields in Iowa; they found more species on minimum-till fields than on disced fields (conventionally- tilled), although the number of small mammals was generally greater in disced fields. Deer mice were the most abundant small mammal species (71% of all captures) in the fields they studied.

Reports of rodent damage to newly planted crops have increased under conservation tillage conditions (Johnson et al. 1982), but the extent of this damage varies. Young and Clark (1984) found an average of 1% damage attributable to rodents in Iowa cornfields, whereas Beasley and McKibben (1976) found damage exceeding 50% in some of their experimental plots in Illinois. Species reported as possibly causing this damage include kangaroo rats, voles, deer mice, house mice, and bog lemmings (Johnson et al. 1982). However, thirteen-lined ground squirrels have been most often cited as causing damage (Stoner 1918, Fitzpatrick 1925, Hisaw and Emery 1927, Nason 1981, Johnson et al. 1982). Despite the damage that some of these rodents cause, the damage susceptible period of the crop is relatively short, generally not more than 3 weeks after corn planting. Furthermore, many rodents have food habits that are generally beneficial. Some of these rodents consume weed seeds and corn-damaging insects (Zimmerman 1965, Whitaker 1966, 1972, Hansen 1975). Grain left on the soil surface after harvest operations is consumed by rodents, thus reducing the potential for undesirable volunteer plants in subsequent crops (K. Holm et al. 1984).

During 1983 and 1984, I evaluated no-till cornfields to determine the small mammal species present and their distributions within fields, the food habits of these small mammals, and the amount of rodent damage to newly planted corn.

STUDY AREAS

Study fields were located in western (Red Willow Co.) and eastern (Saline and Jefferson Cos.) Nebraska (Figure 1). All were farmed without tillage except for the planting operation itself and a single cultivation on two western fields in 1983. Eleven cornfields were sampled in 1983 and 12 different fields in 1984 (Table 1). Crop rotations necessitated sampling different fields each year. Western fields were farmed under the ecofarming system (Wicks 1976) that commonly uses a 3 year crop rotation of wheat - corn or grain sorghum - fallow. Eastern fields had crop rotations of wheat, soybeans, oats, grain sorghum-corn with no fallow periods. Corn planting was delayed until mid to late May in both 1983 and 1984 because of wet field conditions.

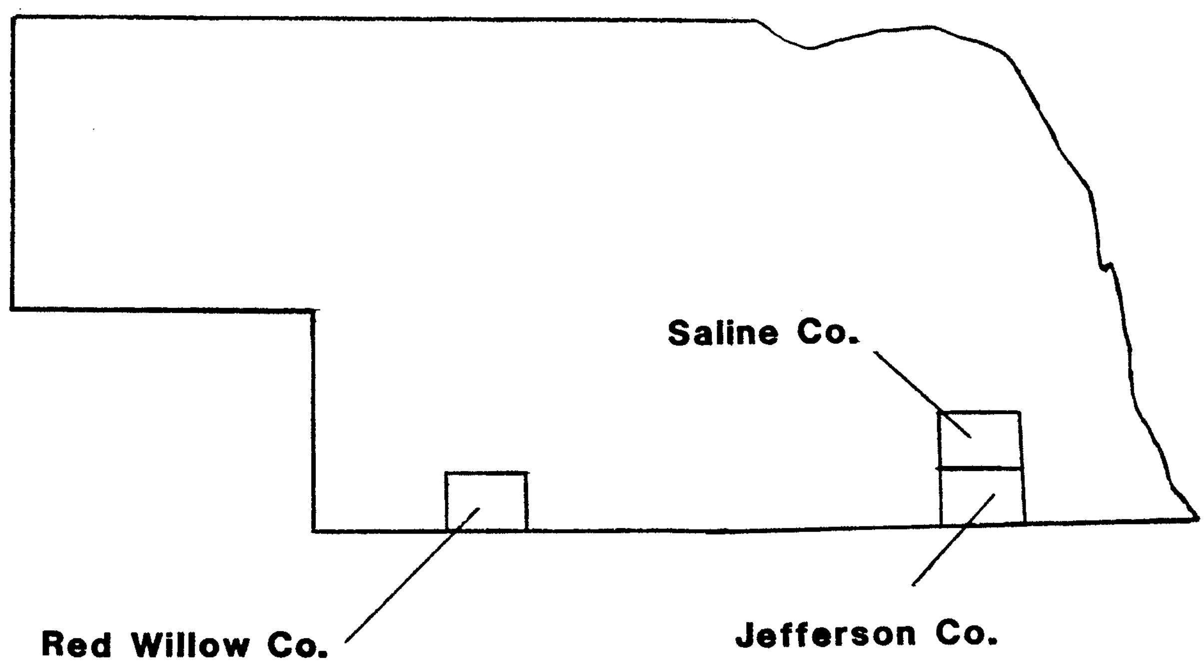

Figure 1. Study areas, Nebraska 1983-84.

Table 1. Location and characteristics of no-tillage cornfields, Nebraska 1983-84.

Field	Field size (ha)	Residue type[a]	Residue cover (%)	County[b]	Legal description
1983					
E-1	2.3	W	93.3 ± 8.4	S	SW1/4,Sec.24,T-5-N,R-1-E
E-2	2.8	W	93.7 ± 13.5	S	SW1/4,Sec.24,T-5-N,R-1-E
E-3	2.5	S	78.4 ± 16.0	S	SW1/4,Sec.24,T-5-N,R-1-E
E-4	8.5	GS	67.5 ± 27.5	S	NW1/4,Sec.25,T-5-N,R-1-E
E-5	5.7	W	93.3 ± 6.7	S	NW1/4,Sec.22,T-5-N,R-1-E
E-6	5.9	W	97.7 ± 6.1	S	SW1/4,Sec.15,T-5-N,R-1-E
E-7	4.9	W	98.8 ± 4.4	J	NW1/4,Sec.3,T-4-N,R-1-E
W-1	19.0	W	95.9 ± 7.9	RW	NE1/4,Sec.6,T-2-N,R-27-W
W-2	19.6	W	84.3 ± 17.2	RW	SE1/4,Sec.22,T-3-N,R-27-W
W-3	18.2	W	94.9 ± 9.8	RW	NW1/4,Sec.5,T-2-N,R-26-W
W-4	26.3	W	95.6 ± 6.2	RW	NW1/4,Sec.6,T-2-N,R-26-W
1984					
E-8	6.8	S	50[c]	S	SW1/4,Sec.17,T-5-N,R-4-E
E-9	13.6	O	50	S	SW1/4,Sec.17,T-5-N,R-4-E
E-10	9.7	S	50	S	SW1/4,Sec.16,T-5-N,R-1-E
E-11	4.9	S	50	S	SW1/4,Sec.15,T-5-N,R-1-E
E-12	5.6	GS	70	S	NW1/4,Sec.22,T-5-N,R-1-E
E-13	4.1	C[d]	70	S	NW1/4,Sec.24,T-5-N,R-1-E
E-14	3.6	W	95	S	SW1/4,Sec.24,T-5-N,R-1-E
W-10	18.2	W	95	RW	SE1/4,Sec.5,T-2-N,R-26-W
W-11	29.9	W	95	RW	SW1/4,Sec.17,T-4-N,R-26-W
W-12	29.5	W	95	RW	SW1/4,Sec.31,T-4-N,R-26-W
W-13	4.7	W	95	RW	SW1/4,Sec.3,T-2-N,R-28-W
W-14	6.1	W	95	RW	NW1/4,Sec.18,T-2-N,R-27-W

[a] W=wheat, S=soybean, GS=grain sorghum, O=oats, C=corn.
[b] S=Saline, J=Jefferson, RW=Red Willow.
[c] Estimated for all 1984 fields.
[d] Planted to corn in 1982, but fallowed during 1983.

METHODS

During 1983, small mammals were trapped after the corn emerged (10-15 days after planting), at maximum corn height, and post harvest, but in 1984, during the post emergence period only. Trap stations consisting of two Museum Special snap traps each were placed at 75 m intervals along transects positioned uniformly across study fields. Transects ran parallel to corn rows and their locations remained constant. To more evenly distribute trapping pressure, trap station locations were shifted 37 m along the transects during the maximum height period and then shifted back to the original locations during the post harvest period (Figure 2). Trapping effort averaged about six traps/hectare. Variation in trapping effort was due to field shape, transect length, and orientation of the corn rows. Traps were baited with a peanut butter and oatmeal mixture, set for 3 consecutive days and nights, checked once per day, and rebaited if necessary. Trapping dates in 1983 were 14-17 June, 12-15 August, and 5-8 November (eastern area), and 2-6 June, 8-11 August, and 29 October-1 November (western area); and in 1984, 24-27 May (east) and 5-8 June (west).

Four transects in each field (two randomly-selected trapping transects, each with a parallel transect 15 rows to the right) were used to measure rodent damage during the post emergence period of both years. Counts of damaged and

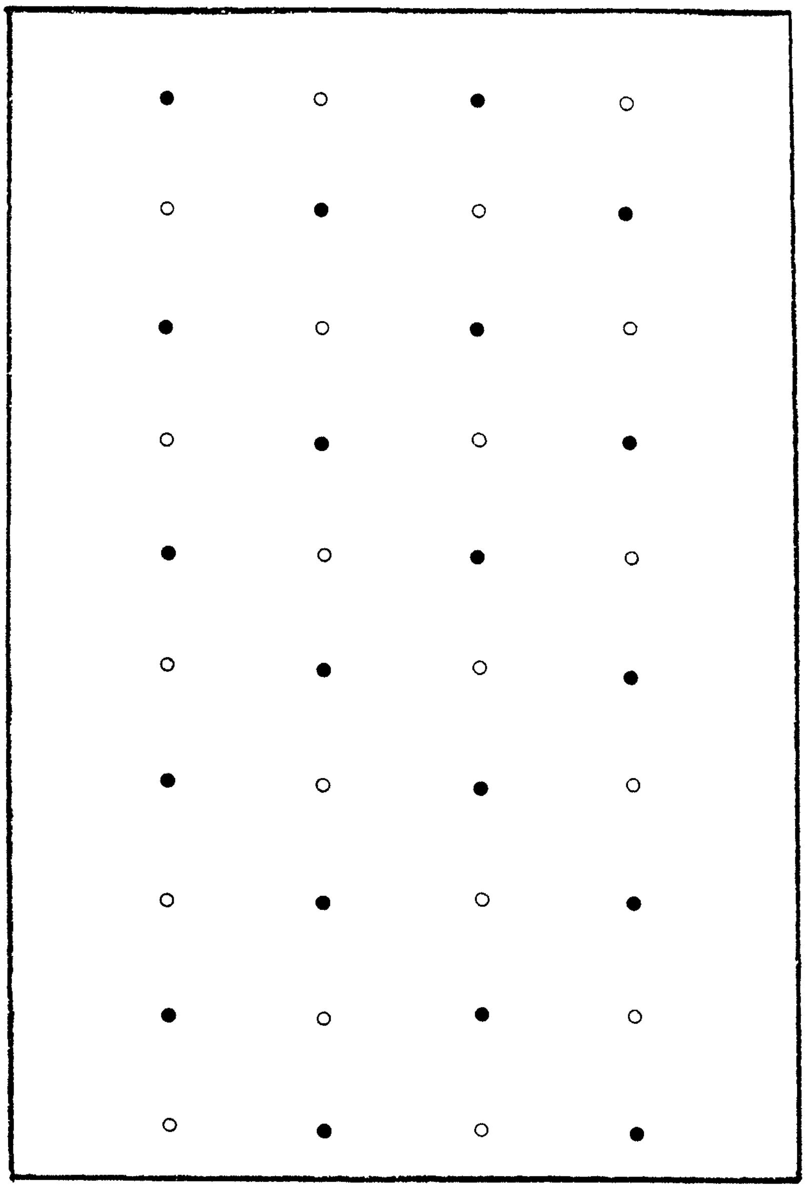

Figure 2. Trap station arrangement, Nebraska 1983.
● = trap station location during the post emergence and post harvest periods.
○ = trap station locations during the maximum height period.

undamaged plants were made along these transects (approximately 15 to 20 days after planting) on every other 30 m section of the corn row. In 1983, 229 30-m sections were counted in the east and 104 in the west; in 1984, 113 sections in the east and 135 in the west. The number of 30 m sections varied among fields because of field size and shape. A seedling was considered damaged by rodents if it had been dug out completely, or if still standing after digging, the seed endosperm had been removed. For each field, the average number of damaged plants was divided by the average count of damaged and undamaged plants to obtain the percent stand loss caused by rodents.

Small mammals removed from traps in the field were placed immediately in insulated containers with ice. Upon return to the laboratory (about 4 days), they were identified, sexed, weighed, and measured, their stomachs removed, and carcasses frozen. Stomachs were placed in a 5% formalin solution in individual plastic vials (60 ml) for at least 48 hours. Stomachs were removed from the vials, contents removed, and the stomachs discarded. Contents were washed with distilled water through a microsieve to remove fluids and to break up large aggregations of food particles. Using dissection and compound microscopes, with the aid of reference specimens collected in the field, contents were identified according to food type as green vegetation, animal material (primarily arthropods/insects), corn seeds, other seeds, or unidentifiable material. Frequency of occurrence (Korschgen 1980) of each food type in the contents was recorded and expressed as the percent of stomachs containing a given food type. Whenever possible, insects and arthropods were identified to order.

T-tests (Steel and Torrie 1980) were used for statistical comparisons between means for relative abundance of small mammals and for damage to newly planted corn. SAS Procedure Correlation (SAS Institute Inc. 1982) was used to identify correlations between the amount of rodent damage and field characteristics including field size, residue amount, area (east or west), year (1983 or 1984), and relative abundance (captures/100 trap nights).

RESULTS

Ten species of small mammals were captured in no-till cornfields (Table 2). Deer mice were the most common, comprising 83% of all captures. Northern grasshopper mice made up nearly 6% of the captures; white-footed mice and hispid pocket mice about 3% each; thirteen-lined ground squirrels nearly 2%; and Ord's kangaroo rats, western harvest mice, voles, and short-tailed shrews less than 1% each.

Captures/100 trap nights was used as an indicator of small mammal relative abundance and was calculated per study area (east or west), trapping period, and year. In the east during 1983, mean relative abundance did not differ among trapping periods ($P < 0.05$) (Table 3). However, in the western area, differences in mean relative abundance were found between the post emergence and post harvest periods and between the maximum height and post harvest periods ($P < 0.05$); there was no significant difference in abundance between the post emergence and maximum height periods ($P > 0.05$).

Captures/100 trap nights for each field was averaged over all trapping periods in 1983. In the east, small mammals were more abundant in two fields (3 and 7) than in the other five fields ($P < 0.05$) (Table 3). In the west, no significant differences were found among any of the four fields ($P > 0.05$).

In 1983, relative abundance of deer mice in cornfields averaged 170 captures/1000 trap nights in the eastern fields (Table 4). Deer mice were significantly less abundant in western than in eastern fields ($P < 0.05$). Relative abundance of deer mice in the western area declined throughout the year and remained relatively low at post emergence in 1984, when different fields were sampled.

Deer mice were captured throughout fields; kangaroo rats and voles were always captured near field borders. Other species showed no clear distribution patterns, partly because of the small number of captures (Table 2).

Table 2. Small mammals captured in no-tillage cornfields, Nebraska 1983-84.

Species	Sex[a]	Eastern area 1983 PE[b]	Eastern area 1983 MH	Eastern area 1983 PH	Eastern area 1984 PE	Western area 1983 PE	Western area 1983 MH	Western area 1983 PH	Western area 1984 PE
Peromyscus maniculatus	M	57	75	46	94	6	78	38	17
	F	47	39	35	81		31	26	9
	Unk	5	5		3	201[c]	16		1
	Total	109	119	81	178	207	125	64	27
Onychomys leucogaster	M		3	5	3	1	9	1	1
	F	2	1	5	2	1	7	1	
	Unk					13[c]	3		
	Total	2	4	10	5	15	19	2	1
Peromyscus leucopus	M	8	6		6				1
	F	7	2	1	5				1
	Unk		1						
	Total	15	9	1	11				2
Spermophilus tridecemlineatus	M	3				1	2		
	F	1	3				1		
	Unk					3[c]			
	Total	4	3			4	3		
Reithrodontomys megalotis	M		2	2			1	1	1
	F			5					1
	Unk		1						
	Total		3	7			1	1	2
Mus musculus	M			3				3	
	F			3					
	Total			6				3	
Perognathus hispidus	M					1	5	1	
	F			1	1		2		
	Unk					10[c]	1		
	Total			1	1	11	8	1	
Dipodomys ordii	M					1	1		
	F					1	3	1	
	Unk					4[c]			
	Total					6	4	1	
Microtus sp.	Unk					8[c]			
Blarina brevicauda	Unk		3						

[a] M=male, F=female, Unk=unknown.

[b] PE=post emergence, MH=maximum height, PH=post harvest

[c] Specimens lost; numbers estimated from field notes.

Table 3. Number of captures and captures/100 trap nights relative abundance) of small mammals in no-tillage cornfields, Nebraska 1983.

	Captures			Captures per 100 trap nights			
Field	PE[a]	MH	PH	PE	MH	PH	$\bar{x} \pm$ S.D.[b]
Eastern Area							
E-1	5	13	4	12	27	10	16.3 ± 9.3
E-2	10	10	3	17	14	5	12.0 ± 6.2
E-3	21	16	22	50	33	52	45.0 ± 10.4
E-4	19	22	21	14	15	15	14.7 ± 0.6
E-5	14	22	18	15	23	19	19.0 ± 4.0
E-6	32	22	11	27	20	9	18.7 ± 9.1
E-7	29	31	27	40	43	38	40.3 ± 2.5
Totals	130	136	106				
Means				25	25	21.1	
S.D.				± 14.8	± 10.3	± 17.4	
Western Area							
W-1	48	27	17	14	8	5	9.0 ± 4.6
W-2	30	25	14	9	10	4	7.7 ± 3.2
W-3	79	33	12	24	13	4	13.7 ± 10.0
W-4	94	78	29	19	17	6	14.0 ± 7.0
Totals	251	163	72				
Means				16.5	12	4.8	
S.D.				± 6.5	± 3.9	± 1.0	
Overall							
Totals	381	303	178				
Means				22	21	15	

[a] PE=post emergence, MH=maximum height, PH=post harvest.
[b] Standard deviation.

Table 4. Captures/1000 trapnights (relative abundance) of small mammals in no-tillage cornfields, Nebraska 1983-84.

	1983						1984	
	Post emergence		Maximum height		Post harvest		Post emergence	
Species	East	West	East	West	East	West	East	West
Peromyscus maniculatus	193.3	139.1	200.3	96.9	142.1	43.4	192.6	51.1
Onychomys leucogaster	3.5	10.1	6.7	14.7	17.5	1.4	5.4	1.9
Peromyscus leucopus	26.6		15.2		1.8		11.9	3.8
Spermophilus tridecemlineatus	7.1	2.7	5.1	2.3				
Reithrodontomys megalotis			5.1	2.3	12.3			3.8
Mus musculus					10.5	2.0		
Perognathus hispidus		7.4		6.2	1.8	0.7	1.1	
Dipodomys ordii		4.0		3.1		0.7		
Microtus sp.		5.4						
Blarina brevicauda			5.1					

Stomach contents of 204 small mammals (nine species) were analyzed to determine food habits. Insects and other arthropods were important food items for seven of the nine species (Table 5). Nearly 100% of northern grasshopper mouse, thirteen-lined ground squirrel, and short-tailed shrew stomachs, and more than 80% of deer mouse and white-footed mouse stomachs contained insect/arthropod foods. Western harvest mice also consumed arthropods, primarily during the maximum height period. House mice had the lowest frequency of occurrence of arthropods (33.3%) but were captured only during the post harvest period.

Lepidoptera larvae were the most common insect food in white-footed mouse stomachs and were a commonly occurring food item in stomachs of deer mice and northern grasshopper mice (Table 6). Sixty percent of the thirteen-lined ground squirrel stomachs contained Lepidoptera larvae. Most Lepidoptera larvae were consumed during the post emergence period in late May and early June.

Coleoptera larvae were consumed by deer mice, northern grasshopper mice, white-footed mice, and thirteen-lined ground squirrels during the post emergence period. Adult Coleopterans were consumed during all periods by all species, with consumption generally increasing from the post emergence to the maximum height periods and then decreasing slightly after harvest.

Orthoptera adults, mainly grasshoppers and crickets, were consumed by at least five small mammal species (Table 6). Thirteen-lined ground squirrels and grasshopper mice were the primary consumers of Orthopterans. Highest consumption of Orthopterans by ground squirrels was at maximum corn height.

Adult Hymenopterans (ants) were consumed by four small mammal species during post emergence and maximum corn height. Spiders (Arachnida:Araneida) and centipedes were present, although rare, in stomachs of deer mice, northern grasshopper mice, and white-footed mice.

Seeds other than corn were consumed by eight of the nine species analyzed, the exception being short-tailed shrews (Table 5). Green vegetation was consumed in varying quantities by all species throughout the study. Nearly all Ord's kangaroo rat and hispid pocket mouse stomachs contained green vegetation (Table 5). Green vegetation was present in the guts of arthropods consumed by small mammals but was not included in determining the frequency of occurrence of green vegetation.

Table 5. Percent of small mammal stomachs containing major food items, Nebraska 1983-84.

Species	Sampling period[a]	n	Corn seeds	Other seeds	Green veg.[b]	Arthropod/ insect
Peromyscus maniculatus	PE-83	20	40	15	30	90
	MH-83	20		90	45	80
	PH-83	20	10	90	55	80
	PE-84	20	30	55	50	90
Onychomys leucogaster	PE-83	4	50		25	100
	MH-83	21	9.5	47.6	33.3	95.2
	PH-83	12	16.7	75.0	58.3	100
	PE-84	3		100	33.3	100
Peromyscus leucopus	PE-83	15	20	20	40	93.3
	MH-83	7		71.4	71.4	85.7
	PE-84	12		41.7	58.3	100
Dipodomys ordii	PE-83	2	50	50	100	
	MH-83	2		50	100	
Perognathus hispidus	PE-83	1	100		100	
	MH-83	8	12.5	62.5	75	
	PE-84	1		100	100	
Spermophilus tridecemlineatus	PE-83	5		20	40	100
	MH-83	6		66.7	100	100
Reithrodontomys megalotis	MH-83	4		100	50	50
	PH-83	7	14.3	71.4	71.4	100
	PE-84	2		100		50
Blarina brevicauda	MH-83	3			33.3	100
Mus musculus	PH-83	9	66.7	88.9	66.7	33.3

[a] PE-83=post emergence 1983, MH-83=maximum height 1983, PH=post harvest 1983, PE-84=post emergence 1984.

[b] Green veg. does not include green vegetation present in the gut contents of ingested arthropods/insects.

Table 6. Percent of small mammal stomachs containing arthropod/insect foods, Nebraska 1983-84.

Species	(n)	Sampling Period[a]	Insect foods[b]: Lep. larvae	Col. larvae	Col. adult	Orth. adult	Hym. adult	Other[c]
Peromyscus maniculatus	20	PE-83	40	10	60	5	15	
	20	MH-83			40	15	10	
	20	PH-83	20		35	15		10
	20	PE-84	55	20	75	15		5
Onychomys leucogaster	4	PE-83		25	25	100	25	
	21	MH-83	14.3		85.7	19.0		
	12	PH-83	8.3		75	16.7		
	3	PE-84	100		66.7	33.3		
Peromyscus leucopus	15	PE-83	46.7	6.7	26.7	6.7	6.7	6.7
	7	MH-83					14.3	14.3
	12	PE-84	83.3	8.3	41.7			
Reithrodontomys megalotis	4	MH-83			25			
	7	PH-83	42.9		14.3			
	2	PE-84				50		
Spermophilus tridecemlineatus	5	PE-83	60	40	40	40	20	
	6	MH-83			50	66.7	16.7	
Mus musculus	9	PH-83	11.1		11.1			
Blarina brevicauda	3	MH-83						100[d]

[a] PE-83=post emergence 1983, MH-83=maximum height 1983, PH-83=post harvest 1983, PE-84=post emergence 1984.
[b] Lep.=Lepidoptera, Col.=Coleoptera, Orth.=Orthoptera, Hym.=Hymenoptera.
[c] Other insects and arthropods including centipedes and spiders.
[d] Contents were unidentifiable.

Some small mammals consumed corn seeds (Table 5). Deer mice, northern grasshopper mice, house mice, and western harvest mice consumed corn in the post harvest period. Five rodent species consumed corn during the post emergence period indicating that they dug up and consumed the planted corn seed. Deer mice, northern grasshopper mice, white-footed mice, Ord's kangaroo rats, and hispid pocket mice all consumed corn during the post emergence period of 1983, but only deer mice consumed corn during the same period of 1984.

Rodent damage to newly planted corn (percent stand loss) varied widely among study fields (Tables 7 and 8). Percent stand loss for the eastern area during 1983 ($\bar{x}$ = 4.7%) was not significantly different from that for the western area ($\bar{x}$ = 8.3%) ($\underline{P}$ > 0.05). However, average stand loss in 1984 was greater in the west ($\bar{x}$ = 1.5%) than in the east ($\bar{x}$ = 0.02%) ($\underline{P}$ < 0.0005).

Several factors including area (east or west), year (1983 or 1984), field size, residue type, residue amount, and relative abundance (captures/100 trap nights), were compared with the amount of damage to determine if correlations existed. Amount of damage was positively correlated with residue amount (i.e. higher residue amounts were associated with higher amounts of damage), however, only about 36% of the variation was explained by this correlation (R = 0.59, $\underline{P}$ = 0.005). Field size was not significantly correlated with relative abundance (R = −0.39, $\underline{P}$ = 0.08) and only 15% of the variation was explained. When correlation analyses were run by area, a positive correlation between relative abundance and damage existed for the western area only (R = 0.89, $\underline{P}$ = 0.007) that explained about 79% of the variation.

Table 7. Rodent damage to newly planted corn in no-tillage cornfields, Nebraska, 1983.

Field	Date sampled	Plants damaged	Stand counts*	Percent rodent damage (stand loss)
Eastern Area				
E-1	15 Jun	77	1195	6.4
E-2	15 Jun	160	1800	8.9
E-3	15 Jun	5	1692	0.3
E-4	15 Jun	12	2914	0.4
E-5	16 Jun	43	3966	1.1
E-6	16 Jun	144	2726	5.3
E-7	16 Jun	280	2673	10.5
	Totals:	721	16,966	$\bar{x} = 4.7 \pm 4.2$
Western Area				
W-1	6 Jun	159	3187	5.0
W-3	6 Jun	200	2112	9.5
W-4	6 Jun	176	1716	10.3
	Totals:	535	7015	$\bar{x} = 8.3 \pm 2.9$

* Undamaged plants and plants damaged by rodents.

Table 8. Rodent damage to newly planted corn in no-tillage cornfields, Nebraska, 1984.

Field	Date sampled	Plants damaged	Stand counts*	Percent rodent damage (stand loss)
Eastern Area				
E-8	1 Jun	0	1746	0
E-9	1 Jun	0	1304	0
E-10	1 Jun	1	1213	0.08
E-11	1 Jun	0	876	0
E-12	1 Jun	1	2008	0.05
E-13	1 Jun	0	696	0
E-14	1 Jun	0	784	0
	Totals:	2	8627	$\bar{x}$=0.02 ± 0.03
Western Area				
W-10	5-6 Jun	83	4293	1.9
W-11	5-6 Jun	80	4591	1.7
W-12	5-6 Jun	39	1900	2.1
W-13	7 Jun	4	976	0.4
	Totals:	206	11,760	$\bar{x}$=1.53 ± 0.8

* Undamaged plants and plants damaged by rodents.

DISCUSSION

Small mammal density (all species) averaged 14.6 captures/100 trap nights (Table 3). Nason (1980) and Timm (1980) reported that small mammal numbers are higher under no-till conditions, however, this may not be the case. In a study in Iowa, Young and Clark (1984) captured more small mammals in spring-disced (conventionally-tilled) cornfields (439 captures) than in minimum tillage cornfields (379 and 332 captures in two types of fields, respectively). Fleharty and Navo (1983) reported densities as high as 105 captures/1000 trap nights for grasshopper mice in conventionally-tilled cornfields in western Kansas.

Although not significant at the 0.05 level, field size and small mammal density (captures/100 trap nights) were weakly correlated ($R = -0.39$, $\underline{P} < 0.08$). It is possible that close proximity to edge habitats is a requirement for some species; Fleharty and Navo (1983) reported that edge habitat may serve as a refugia for small mammals. This idea is consistent with the finding that the small eastern-area fields, with their associated greater amounts of edge, supported larger populations than the large western-area fields. Another explanation for the higher densities found in the eastern area may lie in the overall resource base of the two study areas. Precipitation (generally higher in the eastern area), soil types and other factors may affect rodent densities.

Food habits analyses are helpful in evaluating not only what the animal is eating but also the potential impact of a particular species on the habitat and its economic importance. Insects were consumed by seven species, pointing out this generally beneficial aspect of small mammals. Some species of Lepidoptera larvae (cutworms) feed on young corn seedlings. One cutworm is capable of damaging four to six corn plants (Blair et al. 1981). If small mammals consume some of these larvae, the potential for cutworm damage will be reduced. Deer mice, grasshopper mice, white-footed mice, and thirteen-lined ground squirrels all consumed Lepidoptera larvae during the post emergence period. Damaging insects such as cutworms, wireworms (Coleoptera: Elateridae), and white grubs (Coleoptera:Melolonthinae) may often be clumped in irregular patterns across fields making detection and spot control difficult. Additionally, no-till fields with weed control failure may have increased cutworm problems (D. Keith, pers. comm.). Small mammals, present throughout fields, represent a possible biological control mechanism that may help keep numbers of certain insect pests below the threshold where economic damage occurs.

Deer mice, grasshopper mice, white-footed mice, kangaroo rats, and pocket mice consumed corn in the post emergence period. None of the cornfields had been planted to corn the previous year and no corn was observed prior to planting when fields were thoroughly surveyed. These results indicate that the corn in the stomachs was from the planted crop. Although thirteen-lined ground squirrels are known to damage newly planted corn (Nason 1980, Johnson et al. 1982, Koehler 1983), no corn was found in the five stomachs analyzed, possibly because of the small sample size. Two species (1 pocket mouse, 2 grasshopper mice) consumed corn during the maximum height period; a period when corn (seed) should not have been available. Pocket mice are known for their caching behavior (Scheffer 1938) and this individual may have been feeding on corn seeds stored during the post emergence period. Grasshopper mice generally do not consume seeds until winter when their preferred insect prey is less abundant (Hansen 1975). These mice may occupy the burrows of other small mammals (Bailey and Sperry 1929) and perhaps could have encountered caches of corn seeds.

The amount of rodent damage varied widely among study fields and between years. Some fields experienced severe rodent damage (greater than 10% stand loss) while others received little or none. One might expect the amount of damage to be directly related to rodent density, (i.e. high rodent density = greater damage). This correlation was found in the western area (both years combined) but not in the east. However, because rodent populations in the west were smaller in 1984, but damage overall (east and west)

During the post emergence period, soils in the eastern area (both years) were wet and muddy. On the other hand, western fields, although wet during early to mid May, were dry during the latter part of May and early June in both years and sustained generally more damage. Wet soil conditions may make digging planted corn seeds less desirable because rodents must then expend additional time and energy grooming. The energy gained from the corn seeds may not be enough to offset the loss due to increased maintenance of the pelage. These results indicate potentially less rodent damage in fields or areas of fields with wet soil conditions through much of the damage period.

Other weather effects may also influence the amount of rodent damage. Wet, cloudy, and windy conditions reduce thirteen-lined ground squirrel activity (Schwartz and Schwartz 1981) and may reduce the damage caused by this species. However, delays in planting due to wet field conditions or other reasons may also actually increase the amount of damage by ground squirrels. Johnson et al. (1982) reported that corn planted earlier in the year (1 May) was damaged less than corn planted 15 days or one month later; this observation may relate to increased energy needs for lactation.

MANAGEMENT IMPLICATIONS

Rodent damage to newly planted corn was highly variable. Short-term studies or studies with a small number of replications (fields) may not accurately detect the amount of damage actually occurring. Deer mice comprised about 80% of the small mammal captures in no-till fields; they also caused some damage to newly planted corn. However, it is not known how much of the damage is attributable to deer mice, so targeting controls to deer mice may not necessarily eliminate the majority of the damage. Deer mice were generally distributed throughout no-till fields, therefore any control methods used would probably have to be applied to the entire field. Kangaroo rats, always found near field borders, also caused some damage to newly planted corn; it may be possible to limit control of kangaroo rats to areas near the field perimeter.

Manipulation of edge habitat may be a valuable cultural control technique, especially if rodents such as kangaroo rats that are found near field borders are responsible for most of the damage to corn. However, identification of the primary damage-causing species and the effects of adjacent habitats on these species is needed before cultural control recommendations can be made.

Information gained from this project on the damage-causing species and their food habits provides a preliminary base for evaluating control methods. For

Table 5. Percent of small mammal stomachs containing major food items, Nebraska 1983-84.

Species	Sampling period[a]	n	Corn seeds	Other seeds	Green veg.[b]	Arthropod/ insect
Peromyscus maniculatus	PE-83	20	40	15	30	90
	MH-83	20		90	45	80
	PH-83	20	10	90	55	80
	PE-84	20	30	55	50	90
Onychomys leucogaster	PE-83	4	50		25	100
	MH-83	21	9.5	47.6	33.3	95.2
	PH-83	12	16.7	75.0	58.3	100
	PE-84	3		100	33.3	100
Peromyscus leucopus	PE-83	15	20	20	40	93.3
	MH-83	7		71.4	71.4	85.7
	PE-84	12		41.7	58.3	100
Dipodomys ordii	PE-83	2	50	50	100	
	MH-83	2		50	100	
Perognathus hispidus	PE-83	1	100		100	
	MH-83	8	12.5	62.5	75	
	PE-84	1		100	100	
Spermophilus tridecemlineatus	PE-83	5		20	40	100
	MH-83	6		66.7	100	100
Reithrodontomys megalotis	MH-83	4		100	50	50
	PH-83	7	14.3	71.4	71.4	100
	PE-84	2		100		50
Blarina brevicauda	MH-83	3			33.3	100
Mus musculus	PH-83	9	66.7	88.9	66.7	33.3

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			Insect foods[b]					
Species	(n)	Sampling Period[a]	Lep. larvae	Col. larvae	Col. adult	Orth. adult	Hym. adult	Other[c]
Peromyscus maniculatus	20	PE-83	40	10	60	5	15	
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	20	PH-83	20		35	15		10
	20	PE-84	55	20	75	15		5
Onychomys leucogaster	4	PE-83		25	25	100	25	
	21	MH-83	14.3		85.7	19.0		
	12	PH-83	8.3		75	16.7		
	3	PE-84	100		66.7	33.3		
Peromyscus leucopus	15	PE-83	46.7	6.7	26.7	6.7	6.7	6.7
	7	MH-83					14.3	14.3
	12	PE-84	83.3	8.3	41.7			
Reithrodontomys megalotis	4	MH-83			25			
	7	PH-83	42.9		14.3			
	2	PE-84				50		
Spermophilus tridecemlineatus	5	PE-83	60	40	40	40	20	
	6	MH-83			50	66.7	16.7	
Mus musculus	9	PH-83	11.1		11.1			
Blarina brevicauda	3	MH-83						100[d]

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E-10	1 Jun	1	1213	0.08
E-11	1 Jun	0	876	0
E-12	1 Jun	1	2008	0.05
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E-14	1 Jun	0	784	0
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W-10	5-6 Jun	83	4293	1.9
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The amount of crop residue was positively correlated with the amount of damage ($R = 0.59196$, $\underline{P} < 0.0047$) but this correlation explained only about 36% of the variation in damage. Other factors, which were not measured, may affect both the amount of surface residues available and damage. For example, the amount of residue on the soil surface may relate to the number of years a field has been in no-tillage farming. Under no-tillage systems, soil disturbance is minimal and residues may accumulate.

Species composition differed between the eastern and western areas. Ord's kangaroo rats were found only in the west and hispid pocket mice, although present in both areas, were more abundant in the west. Both of these species consumed corn during the post emergence period and therefore caused some damage. Deer mice were relatively abundant in both areas and caused some damage. However, if deer mice were primarily responsible for the damage, assuming other factors equal, there should have been little difference in the amounts of damage for the two areas. The presence of these two species in the western area may help explain the greater amounts of damage to western fields. However, no conclusions can be made about the impact of particular species until more is known about the influence of other variables between the eastern and western areas.

During the post emergence period, soils in the eastern area (both years) were wet and muddy. On the other hand, western fields, although wet during early to mid May, were dry during the latter part of May and early June in both years and sustained generally more damage. Wet soil conditions may make digging planted corn seeds less desirable because rodents must then expend additional time and energy grooming. The energy gained from the corn seeds may not be enough to offset the loss due to increased maintenance of the pelage. These results indicate potentially less rodent damage in fields or areas of fields with wet soil conditions through much of the damage period.

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MANAGEMENT IMPLICATIONS

Rodent damage to newly planted corn was highly variable. Short-term studies or studies with a small number of replications (fields) may not accurately detect the amount of damage actually occurring. Deer mice comprised about 80% of the small mammal captures in no-till fields; they also caused some damage to newly planted corn. However, it is not known how much of the damage is attributable to deer mice, so targeting controls to deer mice may not necessarily eliminate the majority of the damage. Deer mice were generally distributed throughout no-till fields, therefore any control methods used would probably have to be applied to the entire field. Kangaroo rats, always found near field borders, also caused some damage to newly planted corn; it may be possible to limit control of kangaroo rats to areas near the field perimeter.

Manipulation of edge habitat may be a valuable cultural control technique, especially if rodents such as kangaroo rats that are found near field borders are responsible for most of the damage to corn. However, identification of the primary damage-causing species and the effects of adjacent habitats on these species is needed before cultural control recommendations can be made.

Information gained from this project on the damage-causing species and their food habits provides a preliminary base for evaluating control methods. For example, efficacy of seed-coated repellents may be species-specific; therefore, identification of the species that cause damage is desirable. Stomach content analyses identify beneficial food habits such as the consumption of corn-damaging insects and weed seeds as well as food preferences. Identifying preferred foods may be useful in later studies to determine if alternate feeding (i.e. scattering grain on the soil surface for rodent consumption; discouraging digging) might be an effective control technique. Toxic grain baits that might be used to control rodents would also eliminate their beneficial aspects, including the consumption of crop-damaging insects, weed seeds, and grain left from harvest.

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Appendix 1. Characteristics reported in the literature of small mammals found in Nebraska no-tillage cornfields.

	Lengths (mm)						
Species	Total	Tail	Hind Foot	Ear	Weight (g)	Gestation Period	Litter Size
Peromyscus maniculatus	111-203	41-98	15-25	12-22	9-28	21-23 days	1-9 3-4 common
Peromyscus leucopus	139-212	61-102	19-25	15-19	11-36	21-23 days	2-6
Reithrodontomys megalotis	101-155	61-102	12-19	9-15	9-17	23-24 days	1-7 mostly 3-5
Onychomys leucogaster	135-159	25-61	20-23	14-17	25-43	app. 4 weeks	1-6 avg.4
Spermophilus tridecemlineatus	177-317	60-127	25-41	6-12	113-141 spring 226-255 fall	27-28 days	8-10
Perognathus hispidus	190-247	85-120	24-30	12-14	28-60	N/A	2-6
Dipodomys ordii	244-281	129-156	40-44	12-15	42-78	29-30 days	2-5 avg.3
Microtus spp.	117-186	22-47	14-23	11-16	21-71	21 days	3-4
Mus musculus	127-206	60-101	15-22	11-19	14-28	19-21 days	5-7
Blarina brevicauda	103-141	19-31	13-18	N/A	13-30	N/A	N/A

Appendix 1 (continued).

Species*	Litters/ year	Weaning of young	Sexual maturity	Population density	Longevity	Home range
PM	multiple, but do not breed year-round	2-3 weeks, sometimes 4	females at 5-7 weeks, males somewhat later	25-37/ha	perhaps up to 2 years	small 0.2-0.6 ha
PL	up to 8 with an average of 4	at 3-4 weeks	females at 7 weeks with males later	0.4-16/ha	small % survive to second year	N/A
RM	up to 7 or more	after 2 weeks	most at 3-4 months, females before males	abundant in places	rarely more than 1 year	small 0.2-0.6 ha
OL	2-3	about 3 weeks	both sexes at 4 months, but not in summer of birth	N/A	N/A	about 2.5 ha
ST	1	app. 4 weeks	year following birth	2-8/ha when concentrated	N/A	males up to 4.5 ha, females 1.5 ha
PH	prob. 2	N/A	N/A	N/A	probably does not exceed 2 years	N/A
MS	many, influenced by environment	by 3rd week	females at 25 days, males at 5 weeks	6-16/ha 24-174/ha when abundant	small proportion exceeds 60 days,	restricted less than 0.2 ha seldom past 16 months
MM	13-14 with 5-10 normal	3 weeks	as early as 6 weeks	hundreds/ha under favorable conditions	few live more than 1 year	restricted fairly sedentary

* PM=Peromyscus maniculatus, PL=P. leucopus, RM=Reithrodontomys megalotis, OL=Onychomys leucogaster, ST=Spermophilus tridecemlineatus, PH=Perognathus hispidus, MS=Microtus spp., MM=Mus musculus.

Sources: Jones 1964, Burt and Grossenheider 1976, Schwartz and Schwartz 1981, Jones et al. 1983, Timm 1983.

Appendix 2. Preferred habitat, general habits, food habits, and economic impact, from the literature, of small mammals found in no-tillage crop fields.

Species	Habitat	General Habits
Peromyscus maniculatus	Prefers open areas such as pastures, meadows, and cultivated fields	Spend entire lives in one location; mostly nocturnal; feed during evening and just before dawn; congregate in winter - otherwise solitary
Peromyscus leucopus	Primarily wooded/brushy areas; occurs in open areas with harvested grain that border wooded/brushy areas; dispersing young may inhabit open areas	Spend large amount of time in trees; do not hibernate
Reithrodontomys megalotis	Abandoned fields, meadows, fence rows; areas with dense groun cover; most abundant in sites near water.	Active day and night; prefer to feed just after sunset to about midnight; do not hibernate.
Onychomys leucogaster	Semiarid grasslands and shrublands with sandy/ silty soils for dust bathing; common in fence rows which support high numbers of preferred insect prey.	Highly territorial; do not hibernate; nocturnal.
Spermophilus tridecemlineatus	Flat, open grasslands/ fields wherever cover is short; well-adapted to cropped lawns,golf courses, etc.	True hibernator; diurnal and prefers bright,sunny days with little wind; expend large amounts of energy caching food; solitary.

Appendix 2 (continued).

Species	Habitat	General Habits
Perognathus hispidus	Shortgrass prairies with friable soil and sparce vegetation; upland areas, usually on sites with considerable bare ground.	May be inactive for part of the winter; solitary; do not hibernate.
Dipodomys ordii	Sandy soils, although sometimes found on hard soils; generally not in crop fields but on areas adjacent to fields (rangelands); semi-arid/arid regions; areas with considerable bare soil.	Nocturnal; active year-round; occurs in aggregations but with little social organization; caches large numbers of seeds; do not hibernate.
Microtus species	Upland, herbaceous fields, fence rows, legume fields; dense vegetation.	Well-defined runway systems above and below ground; social with very high reproductive potential; active day and night; short-lived (many only several months).
Mus musculus	Associated with buildings; abandoned fields fence rows; cultivated grain fields (esp. after harvest).	Sedentary with small home range; social, forming colonies; mostly nocturnal; generally live less than 1 year.
Blarina brevicauda	Wet sites in flooded areas or fields covered with heavy, weedy growth; occur less often in grassy cover.	Extremely active; mostly nocturnal but search for food anytime of day or night.

Appendix 2 (continued).

Species	Food Habits	Economic Impact
Peromyscus maniculatus	Omnivorous; insects (beetles and moth larvae), seeds and domestic grains (corn and soybeans); may cache seeds in fall	Abundant prey for predators; consume large quantities of weed seeds and insects; damage some crops and grain stores
Peromyscus leucopus	Similar to deer mouse with utilization of food reflecting availability of those foods.	Similar to deer mouse but prob. does not greatly impact crop areas because of preference for wooded areas; usually present at low densities.
Reithrodontomys megalotis	Mostly herbivorous; seeds of various grasses and legumes, arthropods in spring and summer.	Prey for predators; damage to planted crops is probably minimal due to low population numbers.
Onychomys leucogaster	Mostly carnivorous; adult and larval beetles, other insects and arthropods, other rodents; plant material during winter when few insects are available.	Generally beneficial because of insectivorous habits; negligible injury to crops.
Spermophilus tridecemlineatus	Omnivorous; eats app. equal amounts of plants and animals; grasshoppers, adult/larval beetles, larval moths, seeds/foliage of cultivated grains, waste grain; caches seeds	May damage crops by digging up sprouting corn; consumption of insects offsets detrimental aspects; prey for predators.

Appendix 2 (continued).

Species	Food Habits	Economic Impact
Perognathus hispidus	Mostly herbivorous; mainly seeds which seem to be selected rather than gathered at random; some insects in spring; subsists on large caches of seeds in winter.	Because of its granivorous habits, may damage some planted grain crops.
Dipodomys ordii	Mostly herbivorous; mainly seeds; occasionally eats vegetative parts of plants some insects (spring).	Dig up newly planted seeds; cut off sprouts; most severe damage occurs at high population densities; caching behavior may restrict reseeding; eat waste grain after harvest.
Microtus species	Vegetative parts/seeds of grasses, sedges, and other succulent plants; may eat animal foods; large food caches above and below ground.	Capable of consuming large quantities of food; prey for predators.
Mus musculus	Prefer grain and vegetable products but will eat nearly anything; waste/contaminate more food than is consumed; do not require water.	Very destructive; damage grain and other stored foods spread disease,filth.
Blarina brevicauda	Mostly carnivorous; insects and other arthropods; some plant material (winter); animal food is cached but usually spoils before being eaten.	Beneficial because of its insectivorous habits.

Sources: Bailey and Sperry 1929, Hall and Kelson 1959, Johnson 1961, Burt and Grossenheider 1976, Schwartz and Schwartz 1981, Jones et al. 1983, Timm 1983.

Appendix 3. Wildlife species, other than small mammals, found in no-tillage cornfields, Nebraska, 1983-84.

In addition to the small rodents and shrews present, eight bird, three amphibian, one reptile, and two other mammal species were observed in no-tillage fields. Nests of four bird species were found and the presence of a horned lark fledgling indicated nesting for that species also.

Birds

Horned lark (*Eremophila alpestris*) (fledgling)
Northern bobwhite (*Colinus virginianus*)
Mourning dove (*Zenaida macroura*) (nests located)
Meadowlark (*Sturnella* spp.) (nests located)
Common nighthawk (*Chordeiles minor*)
Ring-necked pheasant (*Phasianus colchicus*) (nests located)
Brown thrasher (*Toxostoma rufum*)
Field sparrow (*Spizella pusilla*) (nests located)

Amphibians

Leopard frog (*Rana* spp.)
Toad (*Bufo* spp.)
Salamander (*Ambystoma* spp.)

Reptiles

Prairie rattlesnake (*Crotalus viridis*)

Mammals

Eastern cottontail (*Sylvilagus floridanus*)
Black-tailed jackrabbit (*Lepus californicus*)

Appendix 4. Mean length and weight measurements for adult[a] small mammals captured in no-tillage cornfields, Nebraska, 1983-84.

			Lengths (mm)				
Species[b]	Sex	n	Total	Tail	Hind Foot	Ear	Weight (g)
PM	M	315	147.6 ± 9.5 (111 - 171)	54.2 ± 6.4 (41 - 66)	18.7 ± 1.0 (12 - 21)	13.6 ± 1.0 (11 - 18)	20.1 ± 3.6 (8.3 - 29.9)
	F	215	150.9 ± 10.0 (117 - 174)	54.7 ± 5.0 (42 - 70)	18.4 ± 0.9 (13 - 21)	13.8 ± 1.1 (11 - 20)	22.2 ± 4.9 (9.0 - 38.9)
PL	M	19	148.2 ± 16.1 (119 - 180)	59.1 ± 9.5 (42 - 76)	19.0 ± 1.9 (17 - 23)	13.6 ± 1.7 (11 - 17)	18.3 ± 6.2 (11.1 - 31.3)
	F	12	158.9 ± 21.3 (135 - 197)	60.7 ± 10.2 (48 - 83)	18.8 ± 2.0 (17 - 22)	14.0 ± 1.3 (12 - 16)	23.4 ± 7.7 (10.4 - 33.5)
OL	M	18	142.5 ± 14.6 (104 - 167)	37.3 ± 4.6 (29 - 44)	21.4 ± 1.0 (18 - 22)	14.6 ± 1.2 (12 - 16)	32.1 ± 10.1 (11.2 - 48.5)
	F	12	153.2 ± 11.0 (137 - 169)	39.3 ± 5.4 (32 - 48)	22.1 ± 0.8 (21 - 24)	15.1 ± 1.2 (14 - 17)	42.4 ± 11.7 (27.6 - 69.2)
ST	M	3	256.7 ± 17.7 (245 - 277)	90.7 ± 6.7 (83 - 95)	35.3 ± 0.6 (35 - 36)	6.7 ± 1.5 (5 - 8)	136.6 ± 18.4 (115.8 - 150.8)
	F	1	272	90	35	7	154.9
PH	M	5	194.4 ± 13.4 (180 - 215)	94.6 ± 8.4 (83 - 105)	26.0 ± 2.2 (25 - 30)	8.2 ± 1.3 (6 -9)	31.1 ± 14.3 (18.7 - 51.2)
	F	4	214.8 ± 18.4 (195 - 235)	99.0 ± 9.6 (85 - 107)	25.5 ± 2.6 (22 - 28)	9.3 ± 1.7 (7 - 11)	49.7 ± 13.7 (34.2 - 60.3)
DO	M	1	235	135	39	7	[a]
	F	3	246.3 ± 10.6 (235 - 256)	130.7 ± 4.0 (127 - 135)	40.0 ± 2.0 (38 - 42)	8.3 ± 1.2 (7 - 9)	61.5 ± 7.6 (56.1 - 66.8)
RM	M	6	136.3 ± 11.4 (122 - 153)	60.3 ± 5.6 (54 - 69)	17.3 ± 0.5 (17 - 18)	12.3 ± 0.5 (12 - 13)	11.2 ± 2.0 (8.3 - 13.2)
	F	6	143.3 ± 8.9 (133 - 155)	61.0 ± 2.6 (58 - 65)	16.8 ± 0.4 (16 - 17)	12.8 ± 1.2 (11 - 14)	13.1 ± 2.8 (9.0 - 17.2)

Appendix 4 (continued).

Species[a]	Sex	n	Lengths (mm) Total	Tail	Hind Foot	Ear	Weight (g)
MM	M	6	166.7 ± 9.0 (158 - 182)	75.0 ± 5.7 (69 - 84)	18.3 ± 0.8 (17 - 19)	12.5 ± 1.5 (11 - 15)	17.6 ± 3.3 (14.0 - 22.7)
	F	2	164.5 ± 9.2 (158 - 171)	73.0 ± 4.2 (70 - 76)	18.0 ± 0 (18)	12.5 ± 0.7 (12 - 13)	18.9 ± 6.1 (14.6 - 23.2)
BB	[c]	3	112.0 ± 3.5 (108 - 114)	19.7 ± 1.5 (18 - 21)	13.0 ± 0 (13)	3.7 ± 0.6 (3 - 4)	12.6 ± 2.0 (11.4 - 14.9)

a Any individual that had reached sexual maturity (i.e. all except juveniles).

b PM=Peromyscus maniculatus, PL=Peromyscus leucopus, OL=Onychomys leucogaster, ST=Spermophilus tridecemlineatus, PH=Perognathus hispidus, DO=Dipodomys ordii, RM=Reithrodontomys megalotis, MM=Mus musculus, BB=Blarina brevicauda.

c Not determined

Appendix 5. Reproductive conditions of small mammals in no-tillage cornfields, Nebraska, 1983-84.

Reproductive condition of small mammals was determined by internal and external examination and expressed as the percentage of individuals in a given condition. Males having scrotal testes were designated as breeding. Females were designated as pregnant (with at least 1 fetus), lactating (with enlarged nipples), breeding (with perforate vaginae); non-breeding females were distinguished from juveniles based on weight (juvenile weight < 10 g). Some females were lactating and pregnant, hence some columns do not add up to 100%.

			Post Emergence 1983		Maximum Height 1983		Post Harvest 1983		Post Emergence 1984	
Species[a]	Sex	Repro. Condition[b]	East	West[c]	East	West	East	West	East	West
PM	M	B	82.5		95.8	96.1	60.9	86.1	90.4	100.0
		NB	10.5		4.2	3.9	37.0	11.1	1.1	--
		J	7.0		--[5]	--	2.2	2.8	8.5	--
	F	L	59.6		69.2	53.6	34.3	69.2	59.3	66.7
		P	38.3		43.6	10.7	5.7	30.8	16.0	--
		B	--		--	--	--	--	13.7	11.1
		NB	14.9		12.8	32.1	62.9	23.1	8.6	--
		J	8.5		--	3.6	--	3.8	18.5	22.2
PL	M	B	87.5		83.3	+[4]	+	+	80.0	100.0
		NB	12.5		16.7	+	+	+	--	--
		J	--		--	+	+	+	20.0	--
	F	L	57.1		50.0	+	100.0	+	40.0	--
		P	42.9		50.0	+	--	+	--	--
		B	--		--	+	--	+	40.0	--
		NB	14.3		50.0	+	--	+	--	--
		J	14.3		--	+	--	+	20.0	100.0

Appendix 5 (continued).

Species[a]	Sex	Repro. Condition[b]	Post Emergence 1983 East	Post Emergence 1983 West[c]	Maximum Height 1983 East	Maximum Height 1983 West	Post Harvest 1983 East	Post Harvest 1983 West	Post Emergence 1984 East	Post Emergence 1984 West
OL	M	B	+		33.3	88.9	20.0	--	66.7	100.0
		NB	+		33.3	11.1	80.0	100.0	33.3	--
		J	+		33.3	--	--	--	--	--
	F	L	50.0		100.0	85.7	--	--	50.0	+
		P	--		--	28.6	--	--	50.0	+
		NB	50.0		--	--	100.0	--	--	+
		J	--		--	14.3	--	100.0	--	+
ST	M	B	66.7							
		NB	33.3			100.0				
	F	L	100.0							
		NB			100.0	100.0				
RM	M	B			100.0	100.0	50.0			100.0
		NB					50.0			
		J						100.0		
	F	L					40.0			100.0
		P					20.0			
		NB					40.0			
MM	M	B					66.7	33.3		
		NB					33.3	66.7		
	F	NB					100.0			
PH	M	NB				100.0		100.0		
	F	L				100.0			100.0	
		NB					100.0			
DO	M	B				100.0				
	F	L				66.7		100.0		
		NB				33.3				

a PM=Peromyscus maniculatus, PL=Peromyscus leucopus, OL=Onychomys leucogaster, ST=Spermophilus tridecemlineatus, RM=Reithrodontomys megalotis, MM=Mus musculus, PH=Perognathus hispidus, DO=Dipodomys ordii.

b B=breeding, NB=non-breeding adult, J=juvenile, L=lactating, P=pregnant.

c Data not available for this time period.

Appendix 6. Small mammals in no-tillage grain sorghum and wheat fields, Nebraska, 1983.

Small mammals were trapped in two grain sorghum and two wheat (recently harvested) fields in the western area during July 1983. All four fields were farmed using the ecofarming no-tillage system (Wicks 1976). Trapping procedures were identical to those used in cornfields during 1983-84.

Five species were captured in the grain sorghum fields but only two in the wheat (Table 9). No small mammals were captured in one of the wheat fields. Deer mice were the most common species, comprising 79.6 and 91.7% of all captures in the sorghum and wheat fields, respectively.

Overall relative abundance (captures/100 trap nights) was much greater in the sorghum than in the wheat fields (Table 10). Relative abundance of deer mice in the grain sorghum was 19.9 captures/100 trap nights compared with only 3.5 in the wheat.

In the wheat fields, wheat seed left on the soil surface after harvest operations may have been more attractive to small mammals than the bait used. Small mammals were present in both wheat fields as evidenced by the caching of wheat seeds underneath some of the snap traps. Daily high temperatures were in excess of 100° F during all three days of trapping and may have discouraged small mammal activity in these fields.

Table 9. Small mammals captured in no-tillage grain sorghum (GS) and wheat (W) fields, Nebraska - 1983.

Species	Field type	Sex: Male	Sex: Female	Sex: Unk*	Total	per 100 trap nights
Peromyscus	GS	47	25	2	74	19.9
maniculatus	W	5	5	1	11	3.5
Onychomys	GS	8	7		15	4.0
leucogaster	W		1		1	0.3
Peromyscus	GS	2			2	0.5
leucopus	W				0	0
Perognathus	GS	1			1	0.3
hispidus	W				0	0
Mus musculus	GS		1		1	0.3
	W				0	0
				Totals	GS = 93	
					W = 12	

* Unk = unknown

Table 10. Captures and relative abundance of small mammals in no-tillage grain sorghum and wheat fields, Nebraska, 1983.

Field	Field size	Trap nights	Captures	Captures per 100 trap nights
Grain Sorghum				
W-6	10.1	168	63	37.5
W-7	13.4	204	30	14.7
		372	93	$\bar{x}$=26.1 ± 6.1
Wheat				
W-8	8.1	132	0	0
W-9	12.1	186	12	6.5
		318	12	$\bar{x}$=3.3 ± 4.6

Appendix 7. Stomach analysis procedures.

1. Reference specimens used in identifying stomach contents were collected in the study fields. Plant materials were generally dried in a plant press. Insects and other arthropods were placed in a 70% ethyl alcohol solution in glass jars.

2. In the lab, stomachs were removed from small mammals using forceps to hold the stomach and a small scalpel to cut the esophagus at the anterior end and the small intestine at the posterior end of the stomach.

3. The intact stomachs were placed in individual 16mm plastic vials and filled with a 5% formalin solution (19 parts formalin, 1 part distilled water) for preservation. With large stomachs (eg. thirteen-lined ground squirrels and grasshopper mice), stomach walls were severed to allow the formalin solution to penetrate the contents.

4. After preservation of at least 48 hours, stomachs were cut open using a small surgical scissors. Contents were emptied from the stomach into a microsieve. Stomachs were washed with distilled water to remove small particles from the stomach wall. After all contents were removed the stomachs were discarded.

5. Contents now in the microsieve were thoroughly washed with distilled water (wash bottle) to remove small food fragments, digestive juices, and formalin.

6. Contents were transferred from the microsieve to the original vial, using distilled water from a wash bottle to help transfer small particles. Vials were then filled with a 70% ethyl alcohol solution (ethyl alcohol + distilled water). At this point the contents were ready to be identified.

7. Contents were emptied from the vial to several petri dishes, the number of dishes depending on the amount of contents. Generally, observation and identification was enhanced by spreading food items uniformly in a dish so that one food item was not directly on top of another. In some cases, the contents were placed in the microsieve and washed with additional distilled water to remove more of the small food particles.

8. One dish at a time was placed under a dissection microscope. Observations and identification of food types were made beginning with the lowest magnification and then zooming in at higher magnifications. All insect and other arthropod identification was made at this stage. Reference specimens of food items likely to be found in the stomach contents were used to help identify contents.

9. Fragments of green vegetation, corn, and/or other seeds were tentatively identified using the dissection microscope. Fragments were placed on a glass microscope slide with a drop of distilled water; crushed and mixed with the water with a dissecting needle and/or forceps.

10. The glass slide was viewed under a compound microscope at the lowest magnification and then at the next highest magnification if needed. Identification of corn was made by comparing the fragments found in the stomach with fragments from known corn seeds.

11. Food items were identified as either corn seeds, seeds other than corn, green vegetation, insect/arthropods, or other. Data were quantified using the frequency of occurrence method (Korschgen 1980). Volume of individual food items in the stomach contents was not measured.

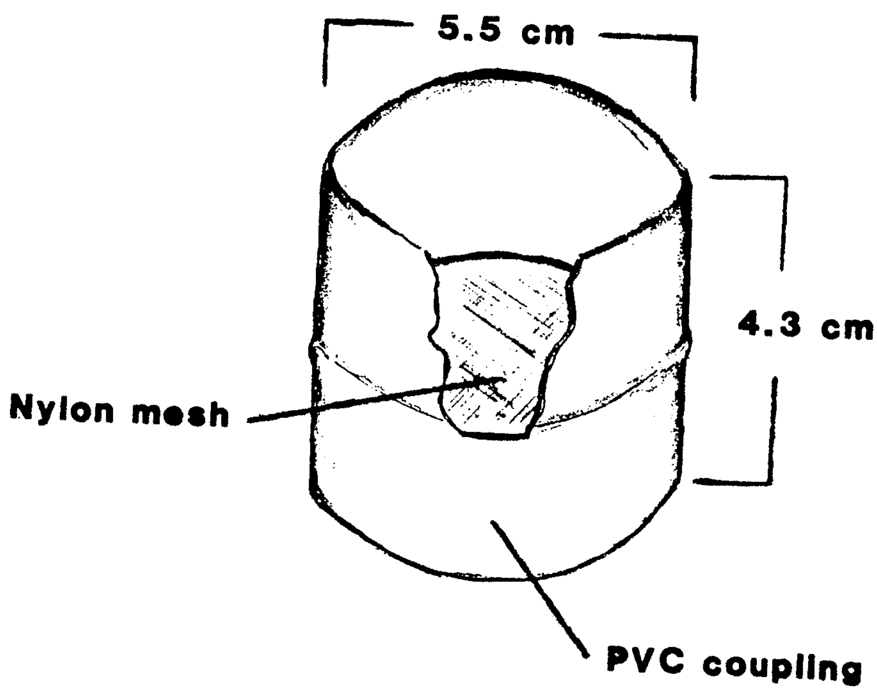

Figure 3. Microsieve used in stomach content analyses.