SMALL MAMMAL USE OF THREE RIPARIAN MANAGEMENT SCHEMES IN SOUTHWESTERN WISCONSIN

by

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TABLE OF CONTENTS

BACKGROUND

Degradation of riparian areas in southwestern Wisconsin

In Wisconsin continuous cattle grazing along streams has caused extensive degradation of riparian habitats (Becker 1983, Wisconsin Department of Natural Resources 1994). Riparian management options are now being considered to improve riparian areas. Traditionally, efforts to improve the health of riparian areas have focused on establishing buffer strips along streams that exclude grazing (Kauffman and Krueger 1984, Barling and Moore 1994, Castelle et al. 1994, Rabeni and Smale 1995). This practice usually leads to improvements in stream quality but is considered impractical by many farmers because buffer strips do not allow continued access to riparian areas for agricultural uses (Platts and Wagstaff 1984). This is particularly a problem in southwestern Wisconsin where the majority of pastureland lies in riparian areas. Farmers who establish buffer strips must compensate for the loss of forage production in these areas by providing food stocks from other sources for their livestock. This often requires farmers to establish additional crop-land on their farms, which increases the amount of labor and capital investment involved in farm operations.

Managed intensive rotational grazing (or MIRG) of livestock has recently been proposed as an alternative to buffer strips for protecting and restoring stream ecosystems in Wisconsin (Undersander et al. 1992). A MIRG system requires a larger pasture area than traditional grazing practices. In this grazing system, the pasture is divided into smaller paddocks that are grazed intensively for a period between 12 hours and 2 days. Each paddock then experiences a "rest" period between 1 and 3 weeks in duration when grazing does not occur. When managed correctly, this grazing regime is believed to promote a thick vegetative turf throughout each paddock, improving stream-bank quality in riparian areas. MIRG systems may also be more economically profitable than continuously grazed pasturing (Undersander et al. 1992). Thus, MIRG systems may satisfy both environmental and socio-economic concerns.

While the socio-economic benefits of MIRG have been demonstrated to some extent (Undersander et al. 1992, Jackson-Smith et al. 1996), the ecological implications of this practice in Wisconsin is undocumented. The Agricultural Ecosystems Research Committee, a group of researchers based out of the Department of Agronomy at the University of Wisconsin in Madison, studied the effect of MIRG, continuous grazing, and buffer strips adjacent to cropland (a farm arrangement that is likely to result if buffer strips are established) in riparian areas. In particular, the group has studied the influence of these farm management options on water quality, fish communities, insects, and terrestrial vertebrates. The terrestrial vertebrate component of this study focused on birds, amphibians, and small mammals. I was responsible for the small mammal portion of this study and the following is a presentation of the results of my research.

Conservation of small mammals in the agricultural landscape

Since European colonization, the landscape of southwest Wisconsin has been transformed from prairie and savannah (Curtis 1959) into a complex and dynamic mosaic of human impacted habitats. Of these habitats, agricultural land uses are the most dominant in southwestern Wisconsin, making up approximately 70% of total land use (Wisconsin Agricultural Statistics Service 1996). Grain cultivation (corn, soybean), hay field, and pasture (25%, 35% and 20% of the total land in farm, respectively) are the most prevalent land uses within this landscape (Wisconsin Agricultural Statistics Service 1996). Although small mammal populations have been dramatically affected, many native small mammal species have persisted, successfully adapting to habitats found in the agricultural landscape (Bowles 1981). Nevertheless, as a result of agricultural changes, several small mammal species are now considered rare in southwestern Wisconsin including the prairie vole (*Microtus ochragaster*), western harvest mouse (*Reithrodontomys megalotus*), and pine vole (*Mirotus pinetorum*) (Anthony 1998).

Livestock grazing will continue to have a dominant presence in areas that were previously native grasslands and savannas. Therefore, conservation efforts in heavily pastured landscapes must be directed toward manipulating grazing strategies and other land use trends to improve or maintain wildlife habitat within the framework of economically achievable land use practices (Holechek et al. 1982, Howe 1994). Recently, conservationists have outlined the need for ecologists to describe systems in relation to land use practices and to work with economists, agronomists and policy developers with the goal of identifying possible scenarios that combine conservation and socio-economic goals (McCracken and Bignal 1998). The possibilities for this type of conservation work are growing as "conservation" and "wildlife habitat" initiatives have worked their way into federal Farm Bill legislation (USDA 1996). Today, the opportunity for combining conservation and socio-economic goals exists as riparian management options in southwestern Wisconsin are considered that will affect future land-use trends.

Small mammals are closely tied to local vegetation structure, which is largely determined by land use patterns. Therefore, small mammals may be an ideal ecological component of the agricultural system to be the focus of the conservation strategy discussed above. However, knowledge of small mammal use of riparian pastures managed in different grazing styles, or left in grassy buffer strips in Wisconsin, is lacking. Therefore, my study will provide new information that may allow managers to improve habitat for small mammals without economic cost to farmers.

Ecological role of small mammals in grasslands

Small mammals perform important ecosystem functions in the grassland system. For example, voles (*Microtus* spp.) are herbivores that influence primary production and local vegetative structure by removing plant matter and pruning vegetation (Grant 1980). Shrew species (*Sorex* and *Blarina* spp.) focus on insect prey, and most small mammal species consume at least some insect matter in their diet. Altogether, small mammals can remove large amounts of insect biomass from a system (Grant 1980). In fact, recent research has suggested that small mammals can control populations of pest insect species such as the gypsy moth (Elkington et al. 1996). Probably the best known ecosystem function of small mammals is as the prey base for birds and larger mammals (Grant 1980, King 1985).

Study objectives

The purpose of my study is to assess small mammal use of riparian areas on continuous and MIRG pastures, as well as vegetative buffer strips adjacent to crop-land in Southwestern Wisconsin. My objectives are to describe the composition of the small mammal communities (Chapter I) and species-habitat relationships (Chapter II) among the three treatments. This information will then be used to discuss the value of these habitats for small mammals as well as the implications my results suggest for potential land use trends (General Discussion).

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CHAPTER I

COMMUNITY-METRICS OF SMALL MAMMAL POPULATIONS IN RIPARIAN AREAS OF THREE FARM MANAGEMENT TYPES

Introduction

Composition and relative abundances of small mammal communities are determined largely by local vegetation characteristics (Bowles and Copsey 1992, Geier and Best 1980, Grant and Birney 1979). Because agricultural land use dictates vegetation characteristics, small mammals respond to land-use practices depending on individual species' habitat requirements. Previous studies have found that some prominent land use practices in the agricultural landscape support a limited small mammal community. For example, disturbances associated with cultivation such as chemical inputs, plowing, planting, and harvesting make corn and other cultivated fields of little value to small mammal species (Marinelli and Neal 1995, Fleharty and Navo 1983). Hayed fields have also been found to support limited small mammal communities (Sietman et al. 1994). Habitats that resemble natural grassy habitats in this landscape appear to support a relatively species rich and abundant grassland small mammal community. Conservation Reserve Program (CRP) fields, restored prairies, and roadside ditches are characterized by relatively high structural complexity that provides the preferred habitat for a broad range of species. These habitats have been found to support relatively diverse small mammal communities (Furrow 1994, Hall and Willig 1994, Kirsch 1997, Anthony 1998), including rare species such as western harvest mouse (*Reithrodontomys megalotis*), prairie vole *(Microtus ochragaster)*, and pigmy landscape (35% of total land in farm, Wisconsin Agricultural Statistics Service 1996). Vegetation structure on pastures results from an interaction between pasture management and growing conditions. Vegetation structural complexity on pastures varies considerably as a result of this interaction and may influence small mammal distributions. Generally, grazing reduces the amount of both live and dead phytomass. Because dense cover is an important habitat requirement for the majority of grassland small mammal species found in southwestern Wisconsin (Table 1), pastures are likely to provide suitable vegetative structure for fewer species than ungrazed grassy habitats. Nevertheless, Geier and Best (1980) found in Iowa riparian areas that heavily grazed wooded pasture as well as grassy habitats that experienced limited grazing, mowing and herbicide applications, supported relatively diverse small mammal communities. However, small mammal associations with land use practices relevant to this study requires further investigation.

This study is designed to test differences in small mammal use of buffer strips adjacent to row crops, continuously grazed pastures, and MIRG pastures. Richness, abundance, diversity indices, and community composition are used to detect differences among small mammal communities on sites under the 3 farm management regimes. Because potential changes in management of riparian areas are likely to influence areas immediately adjacent to streams, I am also interested in detecting a concentration of small mammal activity near the stream.

Hypotheses to be addressed

Hypothesis 1: Buffer sites will support more diverse, abundant, and species-rich small mammal communities than either pasture treatment.

Buffer sites are comprised of two very different cover types: the vegetative buffer strip and crop field. As mentioned above, previous studies suggest that tall, grassy vegetation can support a relatively diverse and abundant small mammal community in non-riparian grassy habitats, while crop fields have been found to support a limited small mammal community, favoring only deer mice *(Peromyscus maniculatus)*. I expected that small mammal communities in buffer strips would be similar to those found in non-riparian grassy habitats with the addition of species that show an affinity for stream areas such as the meadow jumping mouse (Table 1). Pasture sites are generally characterized by a limited amount of cover and litter layer. From Table 1, only 2 of the grassland species listed prefer open areas with relatively little above ground phytomass (deer mice and thirteen-lined ground squirrels). Therefore, conditions on pastures sites are suitable for fewer species of small mammals in southwestern Wisconsin and are expected, regardless of livestock management style, to support a less diverse and abundant small mammal community than the combination of two habitat types on the buffer treatment.

Hypothesis 2: MIRG pastures sites will support more diverse, abundant, and species-rich small mammal communities than continuous pastures.

MIRG pastures are characterized by a cyclical growth pattern between grazing episodes within each paddock. During this "rest" period, above ground live vegetation height increases from about 0.1 m to a height of between 0.5 m and 1.5 m (personal observation). I predicted that species that require greater cover and are common in the agricultural landscape will respond to the development of suitable habitat on MIRG pastures, moving into these areas from adjacent habitats. As a result, MIRG pastures will support a more diverse and abundant small mammal community than continuous pastures.

Hypothesis 3: A concentration of small mammal activity will occur immediately adjacent to the stream compared to 30 m away from the stream on all three treatments.

Several grassland species (Table 1) are known to prefer stream areas or moist soils, which are likely to be associated with proximity to free flowing water. Areas immediately adjacent to streams provide water, a natural "edge" effect, unique vegetation characteristics and greater soil moisture all of which may be attractive to small mammals and concentrate activity in these areas. On buffer sites, the effect of distance to stream will be confounded by differences in vegetative buffer strip and crop habitats. However, I expected that greater small mammal abundance and diversity in buffer strips will result in greater small mammal activity in stream-side areas on buffer sites as well. Therefore, I predicted that regardless of farm management practice, I would observe a concentration of small mammal activity immediately adjacent to the stream.

Methods

Study sites

I sampled small mammals and vegetation from 5 MIRG pastures, 4 continuously grazed pastures, and 4 buffer strips adjacent to planted corn or soybean between May and

September of 1997 and 1998. Study sites were located on cold-water streams in southwestern Wisconsin (Figure 1, Appendix A). All sites were chosen as representative of typical farm management practices for each treatment. All sites had been managed as a pasture or buffer strip for at least 5 years. Sites were selected on streams that supported or potentially supported trout populations to meet requirements of the aquatic study.

MIRG sites

MIRG sites experienced a stocking density of between 50-70 animal units (or au, number of animals in the grazing operation)/ha during grazing episodes. Stocking rates on these sites ranged from 1.4 au/ha/day to 1.7 au/ha/day. Periods between grazing episodes ranged from 2 to 5 weeks, increasing in duration through the summer. Overall, MIRG pastures were 36.5 ha on average (22.0 SD) and paddocks were 3.6 ha on average (3.6 SD). Some MIRG systems also included a additional pastures in nearby riparian or upland areas, increasing the overall pasture size for each farm. Sedge species (*Carex* spp.), bluegrass *(Poa pratensis)*, reed canary (*Phalaris arundinacea)*, quack grass *(Agropyron repens)*, foxtail species *(Setaria* spp.*)*, smartweed *(Polygonum persicaria)*, white clover *(Trifolium repens)*, and dandelion *(Taraxicum officinale)* were common plant species found on these pastures. Following grazing episodes, vegetation height was generally less than 0.2 m, but increased during the rest period to around 0.5 or 1 m. MIRG pastures had little to no litter layer, or build up of dead, matted vegetation (0.0-10.0 cm).

Continuous sites

Continuously grazed sites experienced a stocking density between 0.38 au/ha and 0.97 au/ha. Stocking rates on these pastures were between 0.38 au/ha/day and 0.97

au/ha/day. Pastures 20.0 ha in size on average (14.9 SD). Bluegrass was the dominant plant species found on continuous pastures. Sedge species, white clover, quack grass, jewel weed *(Impatiens palida)*, smartweed . reed canary, and rye grass *(Lolium perenne)* were also common on continuously grazed sites. Vegetation height typically was between 0.2 and 0.4 m throughout the summer. Continuous sites had little to no litter layer (0.0-10.0 cm).

Buffer sites

Buffer sites had a grassy, ungrazed grassy strip between 7 and 15 m in width along each side of the stream and were 1.3 ha on average (0.5 SD). Buffer strips typically connected grassy habitats such as pastures, CRP or hayed fields that were separated by crop-land. Buffer strips were also sometimes associated with a larger network of filter strips along the riparian zone that extended beyond the sampled area. Corn was grown adjacent to this buffer strip on all four sites in 1997. On two sites in 1998, farmers planted soybean in place of corn on at least one side of the stream. Cultivated fields were 13.4 ha on average (6.7 SD). Reed canary grass was the dominant plant species in the grassy buffer strips. Other species found in the buffer strips included sedge species, bluegrass, goldenrod *(Solidago* spp.), smooth brome grass *(Bromus inermis)*, and stinging nettle *(Urtica dioica)*. Vegetation height in the buffer was about 0.8 m in May and increased to about 1.4 m in September. Buffer strips had an extensive litter layer that was typically 10 to 100 cm deep. Cultivated fields were entirely bare ground in May when crops were planted and had matured by late August to approximately 2.0 m and 0.8 m, respectively.

Animal sampling

Trap array

Four 270 m transects were established at each site (Fig. 2). Two transects were established on each side of the stream, one within 5 m of the stream (stream transect) and one approximately 30 m from the stream (non-stream transect). Stream and non-stream results are separated in some analyses and will be discussed as different "locations" within sites. All transects were located parallel to the stream. Transects were placed greater than 30 m from adjacent habitats. When adjacent habitats were within 60 m of the stream, a second non-stream transect was located 30 m beyond the first non-stream transect. Trapping stations were located at 30 m intervals along each transect where two Sherman live traps were placed. The trapping array included 23 medium sized (3" x 3 1/2" x 9" folding, aluminum) and 47 small (2" x 2 1/2" x 6 1/2" both folding and non-folding, aluminum) Sherman live traps. Traps were baited with a wild bird seed mixture containing sunflower seeds, millet, and corn. We selected this bait after experiencing extensive raccoon disturbance of traps when peanut butter and whole oats were used as bait during a pilot study conducted in 1996. We experienced less disturbance of traps with the wild bird seed mixture but did not observe a change in small mammal response to the bait. We used drift fences with pitfall traps to sample species such as shrews that are not effectively captured in live traps (Handley et al. 1993, Anthony 1998). Four 10 meter drift fences, each with 4 pitfall traps, were placed in line with each transect but greater than 50 m from any live trap.

Capture Data

For species other than shrews, individually numbered Monel ear tags (National Band and Tag Co., Newport, Kentucky) were placed on each captured animal. For shrew species, a small dot of paint was placed on the back of the head of each captured animal to identify recaptured individuals. Ear tag number, trap location and number, species, age, sex, mass (measured with a 100 g Pesola scale), body length (nose to beginning of tail), tail, and ear length were recorded at each capture. Small mammals were released at the point of capture.

Animals were aged based on mass and body length. Individuals were considered adults if either body length or mass was greater than 90% of adult sizes reported for Wisconsin populations for each species (Jackson 1961). Field techniques followed guidelines outlined in the *Ad Hoc* Committee on Acceptable Field Methods in Mammalogy (1987). No attempt was made to positively identify species of the genus *Peromyscus* because white-footed mice *(Peromyscus leucopus)* and deer mice are difficult to distinguish in the field in Wisconsin (Anthony 1998). *Microtus* spp. that were suspected to be a species other than *Microtus pennsylvannicus* were collected and a final species determination was made at the University of Wisconsin Zoological Museum. We were also unable to determine positively between *Mustela frenata* and *Mustela erminea;* therefore, these species were grouped as *Mustela* spp. in the results.

Trapping periods lasted for 5 trapping nights. Traps were set on day 1, and checked each morning until day 6 when they were removed. We checked traps a second time at sunset on sites where we expected to capture animals during the day.

Sampling Schedule

Four sites from each treatment were trapped 4 times during 1997 and 1998. Trapping began 15 May and ended 15 September during both years. In 1997 and 1998, trapping sessions at each site were separated by 2 to 4 weeks. We trapped 4 sites at a time, trapping from at least 1 site from each treatment. Eleven of the 12 sites trapped in 1997 were trapped again in 1998. One MIRG site was replaced in 1998 because of a change in livestock management. Because small mammals may respond to growth cycles during the rest period, MIRG sites were sampled at both immediately after and just before grazing episodes. Original captures for each site and year of the study are reported in Appendix B.

Analysis

Calculation of Parameters

The small mammal community was defined as all unique individuals captured over the four trapping sessions from May to September. Trapping methods in this study captured very few juveniles, therefore, only adult captures were included in the analyses. Because of the dynamic nature of small mammal communities from one year to the next, analyses were conducted separately for each year. Relative abundance values for each species were total number of unique individuals captured per 1,000 trap nights. Because the ratio of live-trap to pitfall trap effort was similar for each trapping session, data from the two trap types were combined in capture rate calculations. Effort for relative abundance calculations were corrected for missing, destroyed, and sprung traps:

$$Effort = N - [(0.5)S] - M$$

Where N = total # traps, S = # sprung traps and M = # missing or destroyed traps (Nelson et al. 1973).

Diversity was indexed using species richness, total small mammal relative abundance, the Shannon evenness measure (Pielou 1969), and the Berger-Parker dominance measure (Berger and Parker 1970). Results from stream (> 5 m from stream) and non-stream (< 30 m from stream) transects were compared to detect a concentration of small mammal activity immediately adjacent to the stream. Therefore, richness and relative abundance were calculated for stream and non-stream areas within sites. Berger-Parker dominance and Shannon evenness were calculated for the overall site, combining both stream and non-stream results.

Shannon evenness was calculated as

$$E = \frac{-\sum p_i \ln p_i}{\ln S}$$

where p_i = the proportion of the ith species in the overall community and S = total community richness.

Berger-Parker dominance measure was calculated as

$$d = N_{\max} / N$$

where N = total # of individuals in the sample and $N_{\max}$ = total # of individuals of the most prevalent species in the community.

Investigation of Hypotheses

Shannon evenness (value + 0.01) and Berger Parker dominance (value - 0.01) were arcsine square root transformed prior to analysis to normalize the data (Sokal and Rohlf 1981). Treatment comparisons for these variables were made using a one-way anova ($\propto = 0.05$). A posterior investigation of treatment differences was conducted by using Tukey's honestly significant difference test (Keppel 1991).

Richness and relative abundance data (value +1.0) were $\log_{10}$ transformed prior to analysis to normalize the data (Mosteller and Tukey 1977). Treatment and location (stream and non-stream) differences in richness and abundance were investigated using a repeated measure ANOVA ($\alpha = 0.05$) with stream and non-stream results included as within subject measurements. A posterior investigation of treatment differences was conducted using T-tests with the Bonferroni adjustment for rejection criteria ($= \alpha/m$ where m = # of comparisons) for each pair of treatments for 1997 and 1998 (Keppel 1991). For each T-test, $\alpha = 0.018$ for significant differences (0.05/3) and $\alpha = 0.033$ for tendencies (0.10/3).

I have selected these indices of diversity because they allow comparisons between communities that differ in numbers of individuals and species, and they are sensitive to the separate components of diversity: species richness, relative abundance, evenness (Shannon evenness), and dominance (Berger-Parker dominance) (Magurran 1988).

I used relative abundance for all prevalent species (greater than 10 overall captures) to investigate differences in community structure. Differences in community composition were investigated by comparing percent species composition for all treatments and locations. Results from habitats in this study were compared with those from two studies in Midwest prairie habitats (Kirsch 1997, Anthony 1998). Results from this comparison are included in the discussion.

Results

General results

I captured a total of 1,379 individuals from 14 species during the study (total trap nights [TN] = 37,585 for combined Sherman and pitfall traps). Of these, 343 individuals and 10 species were caught in 1997 and 1036 individuals and 14 species were caught in 1998 (Table 2). At least 10 individuals of *Peromyscus* spp., meadow vole, meadow jumping mouse, short-tailed shrew, masked shrew, western harvest mouse, thirteen-lined ground squirrel, and house mouse (*Mus domesticus*) were captured, and capture rates by treatment and location are reported in Table 3. *Peromyscus* spp. had their highest capture rates on crop fields (i.e., non-stream in Table 3). These species were captured at a slightly lower rate in the vegetative buffer strips and at much lower rates on pastures sites. Meadow voles were captured more frequently in 1998 than 1997 on all treatments. However, in both years, meadow voles were captured most frequently in the vegetative buffer strips (i.e., stream in Table 3). Within each farm management practice, meadow jumping mice were captured more frequently in stream-side areas. But, overall, the most individuals of this species were captured in vegetative buffer strips. Short-tailed shrews and masked shrews were captured most frequently in vegetative buffer strips and were rarely caught on both MIRG and continuous sites. Capture rates of these species on MIRG and continuous sites were greater in 1998 than in 1997. Western harvest mice were captured exclusively on buffer sites during the study. However, in 1997, all captures of this species occurred in the buffer strip, while in 1998 this species was also captured in crop fields that had been switched from corn to soybean. Thirteen-lined ground squirrels were captured more frequently on MIRG and continuous sites than buffer sites. House mice were captured most frequently on buffers sites in crop fields 1998 and were captured infrequently on MIRG and continuos pastures.

Hypotheses

Hypothesis 1 and 2

Small mammal abundance on buffer sites was significantly greater than on continuous pastures (1998, tendency in 1997; Table 4). Buffer sites also supported more abundant small mammal communities than MIRG sites (both years; Table 4). Species richness on buffer sites was significantly greater than on continuous pastures (both years; Table 4). Buffer sites also supported more species rich communities than MIRG sites (1998, tendency in 1997; Table 4). I detected no differences in abundance or species richness between MIRG and continuous pastures (both years).

Species found on buffer sites that were not common on pastures included western harvest mice, masked and short-tailed shrews, house mice and *Peromyscus* spp. Meadow voles were the most abundant species found on both pasture treatments while *Peromyscus* spp. was the most abundant species' captured on buffer sites during both years of the study. In 1997, small mammal communities on all three management types had similar evenness and dominance values (Table 4). However, in 1998, an increase in captures of short-tailed shrews, meadow voles, house mice and western harvest mice on buffer strips caused an increase in community evenness and a decrease in dominance on buffer sites. An increase in captures of short-tailed shrews and a general increase in the number of species represented on continuous pastures in 1998 caused an increase in community evenness and a decrease in dominance on continuous pastures. As a result of these changes in 1998, communities on buffer sites were more even than MIRG communities and both MIRG and continuous communities had higher dominance values (Table 4).

Meadow voles dominated the communities on MIRG and continuous pasture sites in both stream and non-stream areas (Table 6). Although many other species were detected on pasture sites, these species contributed little to the overall community. Communities in stream areas on buffer sites were relatively even, with meadow voles, short-tailed shrews, *Peromyscus* spp. and meadow jumping mice all contributing significantly to the overall community (Table 6). Crop fields on buffer sites were dominated by *Peromyscus* spp., although several other species were captured in these areas in relatively small numbers (Table 6).

Hypothesis 3

I found more abundant and species rich communities in stream areas compared to non-stream areas on MIRG, continuous and buffer sites in both years of the study (Table 5). In 1997, I found more species rich small mammal communities in stream areas compared to non-stream areas regardless of farm management practice (Table 5). In 1998, several species common in buffer strips such as meadow voles, short-tailed shrews and western harvest mice were also captured in the crop fields. As a result, I did not detect more species in stream areas than non-stream areas in 1998 (Table 5).

In 1997, over all sites in this study, an average of 3.6 spp. were close to the stream compared to an average of 2.6 spp. away from the stream in 1997. In 1998, overall, an average of 5.7 spp. were close to the stream compared to an average of 4.3 spp. away from the stream. On MIRG and continuous sites, meadow voles, meadow jumping mice, and short-tailed shrews were more frequently captured close to the stream than away from the stream (Table 3). Of species captured on buffer sites, only *Peromyscus* spp. were typically captured on crop fields away from the stream. Within buffer strips the most common species in 1997 was *Peromyscus* spp. and in 1998, meadow voles were most common. Meadow jumping mouse, short-tailed shrew, masked shrew and western harvest mouse were also common species in buffer strips. *Peromyscus* spp. were overwhelmingly the most prevalent species captured in crop fields. In general, there was an average of 16.0 animals close to the stream compared to an average of 6.3 animals away from the stream in 1997. In 1998, overall, there was an average of 57.1 animals close to the stream and an average of 26.8 animals away from the stream.

Discussion

Hypotheses

Hypothesis 1: Buffer sites will support more diverse, abundant, and species-rich small mammal communities than either pasture treatment.

My data do not provide strong support for hypothesis 1 with respect to diversity of small mammal communities. However, I found greater abundance and richness on buffer sites than either pasture treatment. These results is probably a consequence of the following characteristics of buffer sites. 1) Greater structural complexity on buffer strips within buffer sites provide a greater diversity of micro-habitat types, allowing for more species and individuals to co-exist in the same area. 2) Crop fields provide a second habitat type on buffer sites which support a different community of small mammals from buffer strips. Therefore, results from buffer sites reflect gamma diversity, combining species associated with two distinct habitat types, increasing the total number of species and animals observed in these areas. 3) Buffer sites provided extensive cover for small mammals and are attractive to the relatively large number of cover associated species in southwestern Wisconsin (Table 1).

Hypothesis 2: MIRG pastures sites will support more diverse, abundant, and species-rich small mammal communities than continuous pastures.

My data do not support this hypothesis. Relative abundance and species richness for MIRG sites are not different from communities on continuous sites. In addition, diversity is almost identical for the communities on MIRG and continuous pastures for each year of the study. It may be that the confounding influence of management variables such as haying and grazing intensity overshadowed farm management effects relevant to this study. Vegetation characteristics and their relationship with small mammal populations will be dealt with in more detail in Chapter II.

Hypothesis 3: A concentration of small mammal activity will occur immediately adjacent to the stream compared to 30 m away from the stream on all three treatments.

This hypothesis was supported for all three treatments. This is not surprising on buffer sites based on previous studies of crop fields (Marinelli and Neal 1995, Fleharty and Navo 1983) and ungrazed agricultural grasslands (Furrow 1994, Hall and Willig 1994, Kirsch 1997, Anthony 1998) as well as the habitat affinities of grassland species in southwestern Wisconsin (Table 1).

Peromyscus spp. were the only species that were common on crop fields of buffer sites. *Peromyscus maniculatus* have an affinity for open habitats with a high percentage bare, ground (Baker 1968, Jackson 1961) which was probably responsible for their prevalence in crop fields of buffer sites. High densities of these species in buffer strips may have forced individuals to expand their home range into adjacent crop fields. Nevertheless, buffer strips still supported more rich and abundant small mammal communities than crop-land in 1998.

On both continuous and MIRG pastures, abundance was also greater in stream areas than non-stream areas. Meadow jumping mice were captured almost exclusively in stream areas on both pasture treatments. This result agrees with previous studies that suggest that meadow jumping mice are typically associated with grassy vegetation along streams (Whitaker 1963) and tend to have movement patterns adjacent and parallel to waterways (Tester et al 1993). Meadow voles, *Peromyscus* spp., and short-tailed shrews were also captured more frequently in stream areas. Meadow voles have been found to tolerate flooding and to prefer wet substrate (Lyon 1936, Murie 1969, Jones et al. 1983, Getz 1970). Short-tailed shrews are also believed to prefer moist habitats (Jones et al. 1983). Flooding is a common event along streams in southwestern Wisconsin and these habitats are typically more mesic than non-stream areas increasing the suitability of these areas for meadow voles and short-tailed shrews. *Peromyscus* spp. are not known to prefer stream habitats over other areas although streams may have provided a natural "edge" effect, concentrating the activity of these species immediately adjacent to streams. The concentration of species and animals in stream areas of pasture sites could also be explained by differences in vegetation structure between stream and non-stream areas. This possibility will be explored in Chapter II.

Comparison with results from prairie research

Community structure in buffer strips appeared to be similar to Nebraska prairies and roadside ditches with 5 species contributing greater than 5% but less than 50% to the overall community on these habitats (Table 6). Species composition on habitats in my study is also similar to that found on Nebraska prairies, although prairie voles are relatively rare on pastures and absent from buffer strips but are an important component of prairie and roadside ditch communities. In addition, meadow jumping mice contributed to small mammal communities on all habitats in my study but were not found in the Nebraska study.

Pasture and Wisconsin prairie communities are similar in that meadow voles contributed greater than 50% of individuals to the overall community on both habitat types. However, a larger number of species make a significant contribution to the overall small mammal community on Wisconsin prairie than do on habitats in our study, with *Peromyscus* spp., masked shrew, short-tailed shrew, western harvest mice all contributing more than 5% to the overall prairie community. However, thirteen-lined ground squirrels make a greater contribution to pasture site communities than to Wisconsin prairie communities.

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Table 1. General habitat affinity and preference for cover for species expected to occur in grasslands of southwestern Wisconsin.

Species	Habitat Affinity	Cover Relationship	Prevalence	Source
Meadow vole *(Microtus pennsylvanicus)*	Mesic grassland, high percent forb, wet substrate	Dense cover. Strongly associated with dense litter layer	Common	Geier and Best 1980, Peles and Barret 1996, Snyder and Best 1988
*Prairie vole *(Microtus ochragaster)*	Xeric grassland, high percent forb	Dense cover, prefers less cover than Meadow vole.	Rare	Birney et al. 1976, Cole and Batzili, 1977, Getz 1985
*Pine vole *(Pitymys pinetorum)*	Unknown, well drained woodlands and grassland	Unknown	Rare	Getz 1985
Short-tailed shrew *(Blarina brevicauda)*	Mesic woodlands and grassland	Dense cover. Strongly associated with dense litter layer.	Common	Choate and Fleharty 1975, Jones et al. 1983
Masked shrew *(Sorex cinereus)*	Mesic woodlands and grassland	Dense cover. Strongly associated with high vegetation density	Common	Snyder and Best 1988
*Least shrew *(Cryptotis parva)*	Xeric grassland	Dense cover	Rare	Choate and Fleharty 1975, Whitaker 1974
*Pygmy shrew *(Microsorex hoyi)*	Grassland	Unknown	Rare	Jones et al 1983
Western harvest mouse *(Reithrodontomys megalotis)*	Grassland, high percent forb	Dense cover, litter layer	Rare	Ford 1977, Webster and Jones 1982, Geier and Best 1980
Deer mouse *(Peromyscus maniculatus)*	Open, grassland, high percent bare ground, high percent forb	Low cover	Common	Fleharty and Navo 1983, Baker 1968, Geier and Best 1980.
Meadow jumping mouse *(Zapus hudsonius)*	Grassland along streams, moist substrate	Dense cover, litter layer	Common	Tester 1993, Whitaker 1963
Thirteen-lined ground squirrel *(Speromopholis tridecemlineatus)*	Open, grassland, high percent forb	Low cover	Common	Jones et al 1983, Geier and Best 1980
House mouse *(Mus domesticus)*	Disturbed habitat, associated with human environments, high percent forb	Moderate cover	Common	Fleharty and Navo 1983, Jackson 1961, Geier and Best 1980

*Wisconsin Species of Special Concern

Table 2. Total unique captures by species on 12 southwestern Wisconsin farms (Appendix a) between May and September in 1997 and 1998.

Species	**Captures**	
	1997	**1998**
Meadow vole	104	513
*Prairie vole	0	2
*Pine vole *(Pitymys pinetorum)*	0	1
Short-tailed shrew	22	198
Masked shrew	14	49
*Arctic shrew *(Sorex arcticus)*	0	1
Deer mouse or white footed mouse *(Peromyscus maniculatus* or *Peromyscus leucopus)*	108	107
*Western harvest mouse	5	27
Meadow jumping mouse	68	91
Thirteen-lined ground squirrel	19	28
Eastern chipmunk *(Tamias striatus)*	0	1
Longtail or short-tail weasel *(Mustela frenata* or *Mustela erminea)*	1	2
House mouse	1	15
Norway rat *(Rattus norvegicus)*	1	1
TOTAL	**343**	**1036**

*Wisconsin Species of Special Concern

Table 3. Capture rates of unique individuals (per 1,000 TN) of small mammals captured at 12 southwestern Wisconsin sites, between May and September in 1997 and 1998. Latin names are listed in Table 1.

		Continuous				MIRG				Buffer			
		Stream		Non-stream		Stream		Non-stream		Stream		Non-stream	
Species		x̄	**range**	x̄	**range**	x̄	**range**	x̄	**range**	x̄	**range**	×	**range**
Peromyscus spp.	1997	2.9	0.0-8.9	1.5	0.0-5.9	0.0	0.0	0.3	0.0-1.2	36.6	0.0-85.9	41.4	3.9-75.3
	1998	6.9	0.0-23.8	1.5	0.0-5.8	0.3	0.0-1.2	0.0	0.0	54.6	5.0-109.6	91.7	28.8-133.1
Meadow vole	1997	1.7	0.0-4.1	2.3	0.0-6.4	8.5	0-18.7	2.4	0.0-7.3	26.2	17.8-39.9	2.4	0.0-8.5
	1998	21.0	6.4-34.8	14.9	0.0-45.6	43.9	21.6-81.4	16.4	15.2-18.1	71.3	49.0-87.7	5.2	0.0-13.6
Meadow jumping mouse	1997	1.0	0-4.1	0.7	0.0-2.8	4.4	0.0-14.0	0.0	0.0	24.9	0.0-45.8	1.5	0.0-6.0
	1998	3.9	0.0-11.7	0.0	0.0	4.9	0.0-9.2	0.0	0.0	26.6	10.9-57.5	1.9	1.4-2.5
Short-tailed shrew	1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	1.2-16.4	0.3	0.0-1.2
	1998	3.2	0.0-7.7	1.3	0.0-5.0	5.2	2.4-8.9	1.2	0.0-2.4	48.7	31.0-68.8	5.1	1.6-10.0
Masked shrew	1997	0.0	0.0	0.0	0.0	0.6	0.0-2.3	0.9	0.0-2.3	2.4	0.0-7.1	0.3	0.0-1.2
	1998	0.3	0.0-1.2	0.3	0.0-1.3	1.2	0.0-4.7	4.1	0.0-7.1	8.2	4.9-14.3	1.3	0.0-2.5
*Western harvest mouse	1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0-7.1	0.0	0.0
	1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0-13.4	7.7	0.0-19.6
Thirteen-lined ground squirrel	1997	2.8	0.0-9.9	2.2	0.0-8.9	0.9	0.0-3.7	0.9	0.0-3.7	0.3	0.0-1.2	0.3	0.0-1.3
	1998	4.3	0.0-12.2	3.3	0.0-10.0	0.0	0.0	3.3	0.0-13.3	0.0	0.0	0.0	0.0
House mouse	1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0-1.2	0.0	0.0
	1998	0.3	0.0-1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0-1.5	7.5	0.0-25.8

*Wisconsin Species of Special Concern.

Table 4. Shannon evenness, Berger-Parker dominance, species richness, and relative abundance (# captures/1000 TN) values by treatment and year. Data transformed prior to statistical analysis.

		Continuous		MIRG		Buffer		P-value for treatment difference in ANOVA test
		$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	
Shannon evenness	1997	0.61	0.45	0.60	0.41	0.70	0.13	0.91
	1998	0.69	0.12	0.60	0.11	$0.81^{b(0.02)}$	0.04	0.03
Berger-Parker dominance	1997	0.74	0.24	0.66	0.23	0.51	0.17	0.37
	1998	$0.58^{c(0.03)}$	0.14	$0.69^{c(0.005)}$	0.13	0.34	0.05	0.005
Richness	1997	1.50	0.93	1.75	0.89	$4.00^{a(0.009),d(0.0328)}$	1.77	0.026
	1998	3.37	1.77	3.50	1.51	$6.25^{a(0.0005),b(0.003)}$	1.16	0.001
Abundance	1997	6.29	5.14	8.36	7.71	$37.50^{a(0.018),b(0.008)}$	23.74	0.001
	1998	25.37	17.07	33.82	18.12	$104.83^{a(0.007),b(0.001)}$	56.00	0.014

[a] Greater than continuous results, p-value in parentheses. [b] Greater than MIRG results, p-value in parentheses. [c] Greater than buffer results, p-value in parentheses. [d] Tendency to be greater than MIRG sites, p-value in parentheses.

Table 5. Richness and relative abundance by treatment and location for 1997 and 1998.

		CONTINUOUS				MIRG				Buffer				P-value for location difference in repeated measure ANOVA
		Stream		Non-stream		Stream		Non-stream		Stream		Non-stream		
		x̄	SE	x̄	SE	x̄	SE	x̄	SE	x̄	SE	x̄	SE	
Richness	1997	1.75	0.96	1.25	0.96	1.75	0.50	1.75	1.26	5.50	0.58	2.50	1.00	0.022
	1998	4.75	0.96	2.00	1.15	3.50	1.00	3.50	2.08	6.50	1.00	6.00	1.41	0.112
Abundance	1997	7.00	5.78	5.59	5.19	12.24	8.42	4.48	5.25	57.20	12.25	17.81	11.42	0.012
	1998	33.05	16.00	17.69	16.33	41.7	20.99	23.89	7.90	151.54	30.7	58.12	23.56	0.003

Table 6. Community structure by location and treatment for this study and for two studies in Midwest prairies. Key is at bottom of table.

Species	Continuous		MIRG		Buffer		Nebraska (Kirsch 1997)		Wisconsin (Anthony 1997)
	Stream	Non-stream	Stream	Non-stream	Stream	Non-stream	Ditch	Prairie	
Meadow vole	◉	◉	◉	◉	⚫	●	●	⚫	◉
*Prairie vole	•		•				⚫	●	•
*Pine vole				•	•				
Short-tailed shrew	●	●	●	•	⚫	●	●	●	●
Masked shrew	•	•	•	⚫	●	•		•	●
*Pygmyshrew									•
*Arctic shrew				•					
Peromyscus spp.	●	●	•	•	⚫	◉	⬤	●	⚫
*Western harvest mouse					•	●	●	⚫	●
Meadow jumping mouse	●	•	●	•	⚫	•			•
Thirteen-lined ground squirrel	●	⚫	•	●	•	•	•	•	•
Eastern chipmunk						•			•
Weasel				•	•				
House mouse	•				•	●	•		
Norway rat					•				

• 0.1%-5.0%, ● 5.1%-15.0%, ⚫ 15.1%-30.0%, ⬤ 30.1%-50.0%, ◉ >50.0% of overall community.

*Wisconsin Species of Special Concern. [a]Kirch (1997) used Sherman livetraps only. [b]Anthony (1998) used Sherman and Longworth livetraps and a small number of pitfall traps without drift-fences.

Figure 1. Location of Study Sites.

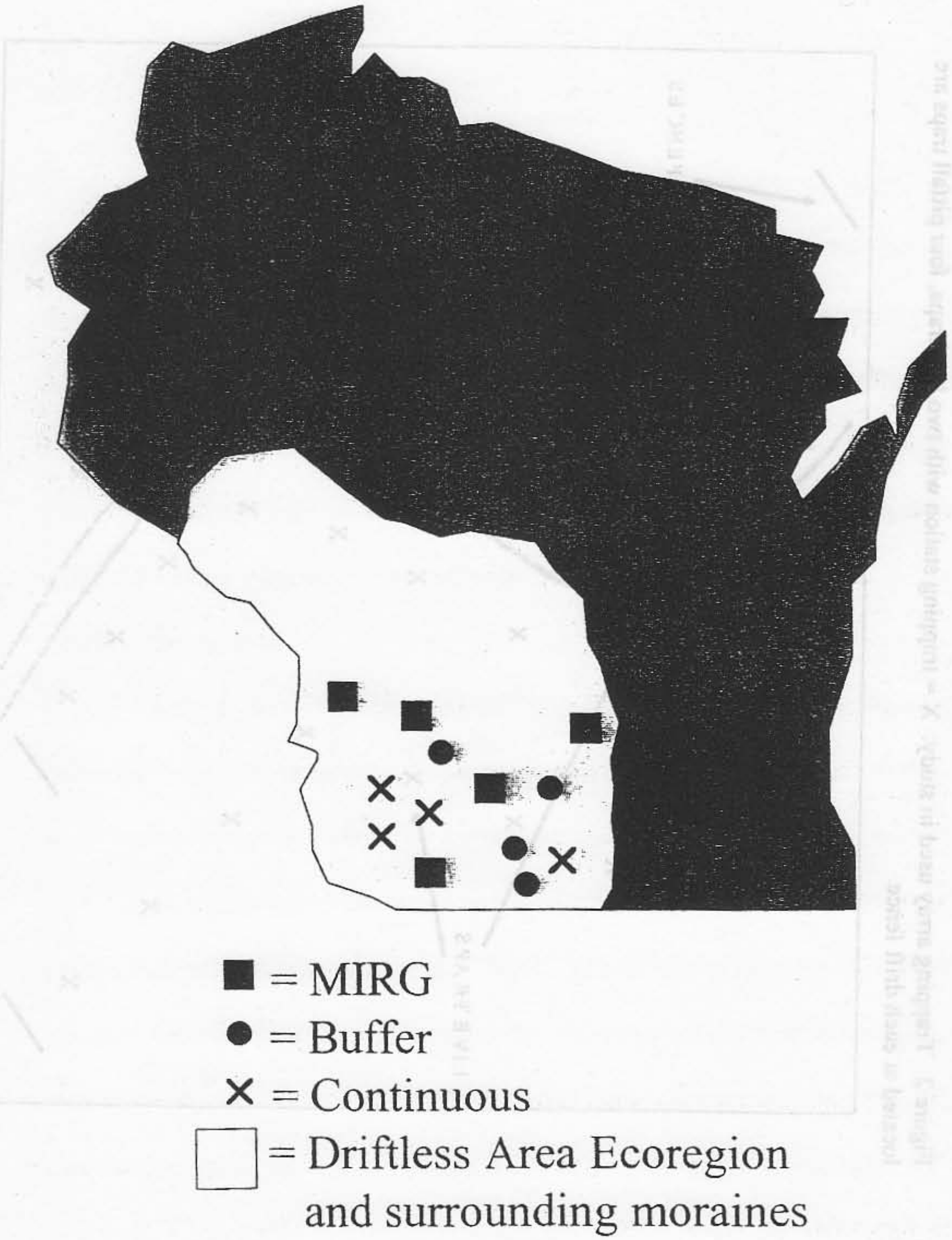
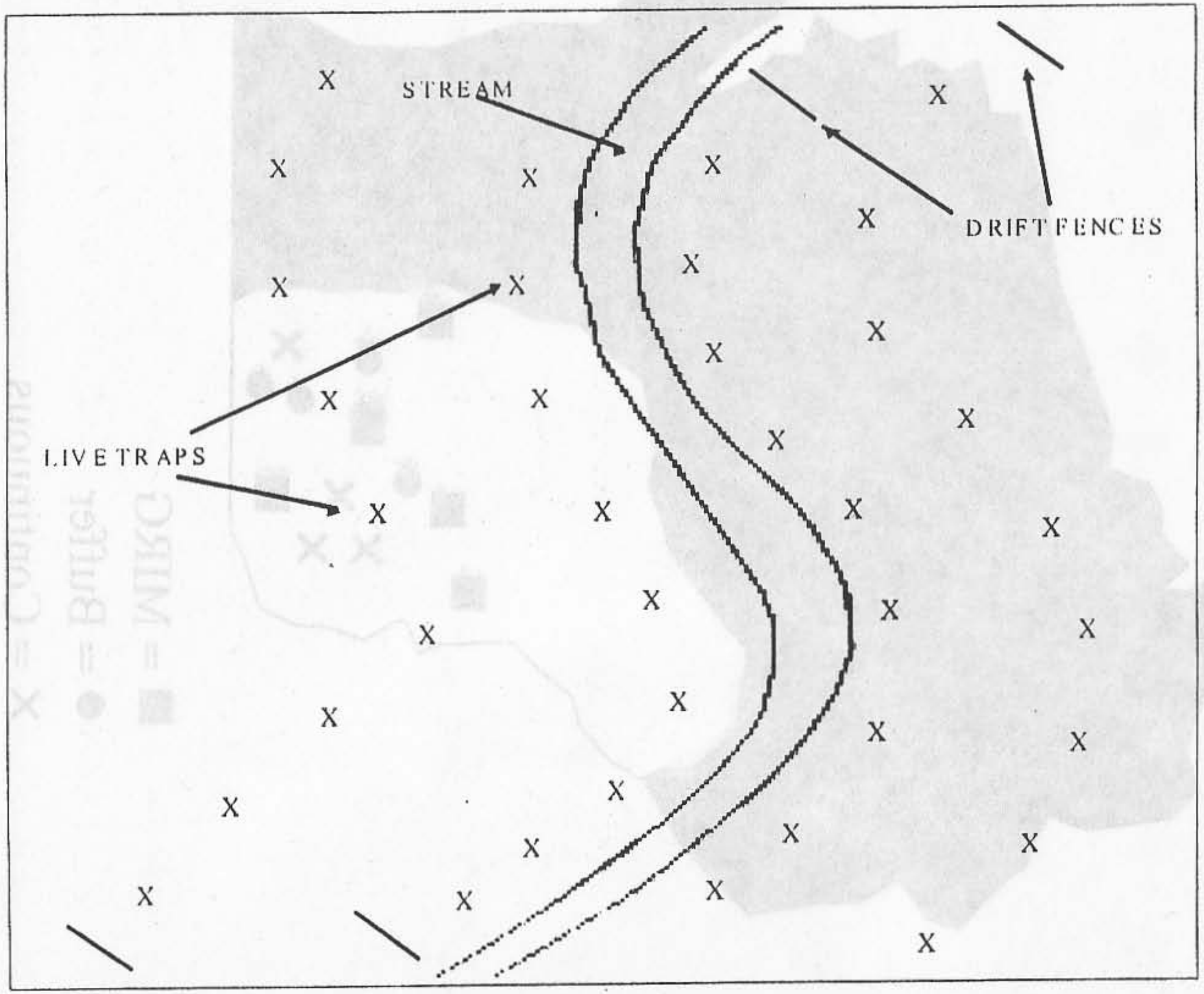


Figure 2. Trapping array used in study. X = trapping station with two live traps, four pitfall traps are located at each drift fence



CHAPTER II

INFLUENCE OF COVER ON SMALL MAMMAL ABUNDANCE

Introduction

Grassland small mammal species are known to be sensitive to above-ground vegetation structure (Clark et al. 1989, Hayslett and Danielson 1994, Kurta 1995, Peles and Barrett 1996). For many grassland small mammal species, cover provides food, protection from predators, and a favorable microclimate during extreme temperatures (Birney et al. 1976). Therefore, I test the influence of cover provided by both live and dead vegetation on small mammal results discussed in Chapter I. In this chapter, I focus on the pasture sites only, and then on areas near the stream regardless of treatment.

Pasture investigation

I did not detect differences in small mammal communities on continuous and MIRG pastures (Chapter I); therefore, I was interested in investigating how much of the variability in the results from pasture sites overall could be explained by differences in cover variables.

First, I investigated how much of the differences observed between stream and non-stream areas in small mammal results (Chapter I) could be explained by differences in cover variables between these two areas. Secondly, I investigated the relationship between species abundance and vegetation structure in stream and non-stream areas. Several grassland small mammal species captured in this study prefer habitat characteristics associated with stream-side areas. Other species prefer dry soils and are expected to be associated with non-stream areas. These species may be found within their preferred stream or non-stream habitats for reasons other than vegetation structure. If this is the case, I expected these species to be less closely associated with suitable vegetation structure in these areas. Therefore, I investigated the relationship between cover variables and species abundance separately in stream and non-stream areas.

Stream-side investigation

Previous studies have suggested that for meadow voles, abundance begins to increase at a threshold level of cover (threshold I, Fig. 1) and continues to increase until reaching a second threshold (threshold II, Fig. 1) (Snyder and Best 1982, Peles and Barrett 1996, Birney et al. 1976). This relationship with cover may exist for other species in addition to meadow voles that require cover in grasslands. I tested the following models to investigate this hypothesized relationship.

Linear model

If cover variables from pasture sites and buffer sites fall between Threshold I and Threshold II (Fig. 2), small mammal abundances should increase according to a linear model (Fig. 3):

$$\text{Abundance} = m\,(\text{Vegetation variable}) + b$$

where "m" equals the slope of the line and "b" is the y-intercept.

Threshold model

If cover variables from pasture sites begin above Threshold I but cover variables on buffer strips lie beyond Threshold II (Fig. 4), then I would expect to observe an immediate rise to an asymptote in small mammal abundance as cover levels increase (Fig. 5). In this case, abundances would be predicted by the following model that incorporates a threshold level and an asymptote:

$$\text{abundance} = a\,(1 - e^{-\text{vegetation variable} * (b)})$$

where parameter "a" controls the location of the ceiling asymptote on the Y axis, and parameter "b" controls the slope of the increase prior to the asymptote and the location of the threshold along the vegetation cover axis (Fig. 5).

The objective of this chapter is to investigate the models described above for small mammal abundances within pastures and within stream areas.

Methods

Vegetation sampling

Vegetation variables were sampled during each small mammal trapping session. Vegetation-height-density and litter layer depth were used to index the amount of available cover. Four litter layer depth (cm) measurements were taken within a ½ m by ½ m square sampling station immediately adjacent to each live trap and drift-fence. Visual obstruction readings at 4 m from a Robel pole at a height of 1 m were also taken at each sampling station (Robel et al. 1970). Vegetation sampling was not conducted in non-stream areas of buffer sites to avoid damaging crops. Mean values for each cover variable was calculated for stream and non-stream transects as well as for the overall site for each session.

Mean Robel height and litter depth values for cover variables were summarized for 1997 and 1998 by treatment and location and presented in tabular form. Because of missing data, Robel and litter depth measurements from the first 2, rather than all 4 trapping sessions were averaged for both years.

Model formulation

I began by conducting a literature review to describe the relationship with cover for each species with greater than 10 captures in this study (Table 1). I then used this information to predict relationships between the amount of live and dead cover and relative abundance for common species and overall small mammal abundance (Table 2). Capture rates were used to index small mammal abundance for this analysis. Capture results and vegetation data were then used to test predictive models in a regression format.

Model testing

In 1997, a small number of animals and species were captured on MIRG and continuous sites (Chapter I). Therefore, the relationship between vegetation and small mammal community variables was investigated for 1998 only.

Cover values by site and location (stream and non-stream) were calculated by averaging results from vegetation sampling from all 4 trapping sessions in 1998. Small mammal capture rates were averaged over all 4 trapping sessions for stream and non-stream areas for all species separately and combined. Species included in each investigation had at least 10 overall captures within that investigation. In addition, capture rates of all species combined were included in each investigation. Small mammal capture rates were $\log_{10}$ (value + 1.0) transformed prior to analysis to normalize the data (Mosteller and Tukey 1977). SYSTAT 7.0 was the statistical package used for this analysis.

Pasture investigation

Species abundance differences between stream and non-stream areas

Paired t-tests were used to investigate differences between stream and non-stream capture rates by species and for all species combined. I also tested for differences in litter depth and Robel height between stream and non-stream areas. Results were reported in tabular form. Significance was set at $\propto = 0.05$ for these tests.

Species abundance relationship with vegetation in stream and non-stream areas

The role of vegetation differences between stream and non-stream areas was investigated for small mammal variables that showed a tendency ($0.05 < \text{p-value} \leq 0.10$) or a significant ($\text{p-value} < 0.05$) preference for stream or non-stream areas. In this analysis, differences between stream and non-stream values for Robel height [Robel height $_{(S\text{-}N)}$], litter depth [litter depth $_{(S\text{-}N)}$] and small mammal abundance [capture rate $_{(S\text{-}N)}$] were calculated for each site. The relationship between litter depth $_{(S\text{-}N)}$ and Robel height $_{(S\text{-}N)}$ with capture rate $_{(S\text{-}N)}$ was then investigated in a linear regression format. Predictive ability based on R^2 values and residual plots were used to assess the influence of these cover variables on species abundance. I tested the following models for each mammal variable:

1) Capture rate $_{(S\text{-}N)}$ = Constant + Robel height $_{(S\text{-}N)}$

2) Capture rate $_{(S\text{-}N)}$ = Constant +litter depth $_{(S\text{-}N)}$

3) Capture rate $_{(S\text{-}N)}$ = Constant + Robel height $_{(S\text{-}N)}$ +litter depth $_{(S\text{-}N)}$

Within-location comparisons

The influence of Robel measurements and litter depth on small mammal abundance was investigated for stream and non-stream areas separately. Results from stream or non-stream areas were not analyzed if fewer than 3 sites were occupied by a species in a location. Models tested in this investigation included:

1) Capture rate = Constant + Robel height

2) Capture rate = Constant + Litter depth

3) Capture rate = Constant + Robel + Litter depth

Results were compared to general predictions made in Table 2.

Stream-side investigation

I tested the usefulness of Robel height and litter depth values from stream areas in explaining variability of small mammal abundances in stream areas in 1998. Linear and non-linear models outlined in the introduction were fitted to the data. Non-linear models were not conducted for thirteen-lined ground squirrels and *Peromyscus* spp. because I expected cover variables to have a negative, linear relationship with abundance for these species. The following models were tested:

Linear models:

1) Capture rate = Constant + Robel height

2) Capture rate = Constant + Litter depth

Non-linear (threshold) models (see Introduction):

1) Capture rate = a (1 - $e^{-\text{litter depth} * (b)}$)

2) Capture rate = a (1 - $e^{-\text{Robel height} * (b)}$)

Models were assessed by examining residual plots and predictive ability based on, R "Observed vs predicted" square for non-linear regressions or R^2 values for linear regression. Predictive ability and residual plots were used to assess the influence of robel height and litter depth on abundance for each species. Results were compared with general predictions stated in Table 2.

Results

Vegetation

Robel height and litter depth were slightly higher on MIRG pastures than continuous pastures in stream and non-stream areas in both years of the study (Table 3). As expected, the highest cover values occurred in the buffer strips (Table 3). Robel height increased slightly in 1998 on both pasture treatments and on buffer strips (Table 3). In 1998, litter depth decreased on pasture sites in non-stream areas, but increased on buffer strips (Table 3).

Pasture investigation

Species abundance differences between stream and non-stream areas

All small mammals combined, short-tailed shrews and meadow jumping mice had higher capture rates in stream areas than non-stream areas (Table 4). Meadow voles tended to be more frequently captured in stream areas than non-stream areas, while masked shrews tended to be more frequently captured in non-stream areas (Table 4). Neither *Peromyscus* spp. nor thirteen-lined ground squirrels were captured more frequently in stream or non-stream areas.

For cover variables, I found no differences between stream areas and non-stream areas for Robel height (stream: mean = 0.90 dm, SD = 0.22; non-stream: mean = 0.82 dm, SD = 0.34; paired t = 0.899, df = 7, p = 0.40). However, litter depth tended to be lower in stream areas (stream: mean = 2.8 cm, SD = 0.7; non-stream: mean = 4.4 cm, SD =2.1; paired t = -2.269 , df = 7, p = 0.06).

Species abundance relationship with vegetation in stream and non-stream areas

Higher capture rates for meadow voles in stream areas was in part explained by greater Robel height next to the stream (Table 5). For the short-tailed shrew and the meadow jumping mouse, greater capture rates in stream areas were not explained by differences in cover levels between stream and non-stream areas. I found some evidence that greater overall small mammal capture rates near streams is influenced by the amount of litter layer in stream areas relative to non-stream areas (Table 5). However, differences in vertical density between stream and non-stream areas did not explain higher capture rates observed for all species combined in stream areas. Overall, there was little evidence that differences in results on pastures between stream and non-stream areas was driven by differences in litter depth or vertical density.

Within-location comparisons

Meadow vole

Within stream areas, cover variables were not useful in explaining variability in capture rates for meadow voles (Table 6). In non-stream areas, however, capture rates for meadow voles were higher where Robel measurements were higher and where the litter layer was deeper (Table 6). The positive relationship with Robel height and stronger relationship with cover in non-stream areas agreed with my predictions (Table 2). However, these results were contrary to my prediction that litter depth on pastures would occur in quantities insufficient to influence meadow vole abundance.

Short-tailed shrew

Regardless of the location, none of the models tested for short-tailed shrews were significant in explaining variability in capture rates of this species (Table 6). However, in non-stream areas, short-tailed shrews were more frequently captured where the litter layer was deeper (Table 6). This supports the prediction that a stronger relationship with cover for this species is found in non-stream areas, but not the prediction that short-tailed shrews are positively associated with Robel height and not litter depth (Table 2).

Masked shrew

Models were not tested for results from stream areas because of the infrequency of masked shrews in stream transects. Therefore, I was unable to address the prediction that masked shrews are more closely tied with vegetation structure in non-stream areas than stream areas. In non-stream areas, neither litter depth nor Robel height alone were useful predictors of variability in masked shrew capture rates (Table 6). However, I found weak evidence that masked shrews are more abundant were both the litter layer is deeper and Robel measurements are higher (Table 6). This result supports the prediction that masked shrews are positively associated with Robel height alone.

Meadow jumping mouse

Models were not tested for results from non-stream areas for this species because of the infrequency of meadow jumping mice in non-stream transects. Therefore, I was unable to address the prediction that this species is more strongly associated with vegetation structure in non-stream areas. In stream areas, cover variables were not found to be significant predictors of meadow jumping mouse abundance (Table 6). This does not support the prediction that Robel height is positively associated with capture rates of meadow jumping mice.

Thirteen-lined ground squirrel

Cover variables were not useful in explaining variability in capture rates for thirteen-lined ground squirrels in non-stream areas (Table 6). However, in stream areas, there was a negative relationship between thirteen-lined ground squirrel abundance and both Robel height and litter depth (Table 6). This supports the prediction that thirteen-lined ground squirrels have a stronger, negative relationship with cover variables in stream areas than in non-stream areas. It does not, however, support the prediction that Robel height is the only cover variable important for this species in pastures.

Peromyscus spp.

Models were not tested for results from non-stream areas because of the infrequency of *Peromyscus* spp. in non-stream transects. Therefore, I was unable to address the prediction that this species is more strongly associated with vegetation structure in stream areas than non-stream areas. In stream areas, there was a negative relationship between Robel height and *Peromyscus* spp. capture rates (Table 6). This supports my prediction that *Peromyscus* spp. abundance has a negative relationship with cover variables. It does not, however, support the prediction that Robel height is the only cover important for this species.

All species

Cover variables were not useful in explaining variability in capture rates for all species combined in stream areas (Table 6). In non-stream areas, however, there was a positive relationship between both cover variables and capture rates for all species (Table 6). In particular, more small mammals were captured where the litter layer was deeper.

Stream-side investigation

Meadow vole

According to the linear model, meadow vole and all species combined capture rates were positively associated with Robel height and litter depth (Table 7 , Fig. 6). However, residual plots for the linear model for both litter depth and Robel height in the case of meadow voles and all species combined. indicated a greater lack of fit at lower estimated values (Figs. 7, 8). The non-linear model for meadow vole and all species combined provides evidence for a positive relationship between each cover variable and capture rate with an asymptote. The residual plots for these analyses do not indicate any problems with the non-linear model. Therefore, this model more accurately describes the relationship between cover variables and meadow vole and all species combined capture rates than the linear model. These results support the model predicted for the meadow vole and all species combined.

Short-tailed shrew and meadow jumping mouse

The linear model demonstrated that Robel height and litter depth were positively related to short-tailed shrew and meadow jumping mouse capture rates (Table 7). The non-linear model provides some evidence that the positive relationship between cover variables and capture rates also has an asymptote (Table 7). However, the lack of data between low and high litter layer levels limited my ability to detect the presence of a threshold in the positive relationship between litter depth and abundance (Fig. 9). Residual plots also do not clearly support one model over the other (Figs. 10,11). Nevertheless, inspection of the fitted models against the data suggests that the positive relationship between Robel height and meadow jumping mouse and short-tailed shrew abundance may have an asymptote (Fig. 9). These results support my hypothesis that there is a positive relationship between cover variables and abundance for these species, but are inconclusive in determining the presence of an asymptote in this relationship.

Thirteen-lined ground squirrel

I did not find evidence for a relationship between either cover variable and capture rates of thirteen-lined ground squirrels (Table 7, Fig 12). Furthermore, residual plots for these models do not meet the assumption of constant variance for all estimated values (Fig. 13). Therefore, results do not support a negative relationship between cover and abundance for thirteen-lined ground squirrels.

Peromyscus spp.

My results support a positive linear relationship between both cover variables and capture rates of *Peromyscus* spp. (Table 7, Fig. 12). However, residual plots provide some evidence against this relationship for litter depth because of limited information between low and high litter depth levels (Fig. 13). Also, these results do not support the predicted negative relationship between cover and abundance for *Peromyscus* spp.

Discussion

Pasture investigation

Overall, greater capture rates in stream areas do not appear to be caused by differences in vegetation structure between these areas. In addition, species that prefer stream areas do not appear to be closely associated with the structure of above-ground vegetation next to the stream. Therefore, my results suggest that stream areas are attractive to some small mammal species on pastures for reasons other than vegetation structure.

Specific evidence for this is found in the results from the pasture investigation for meadow voles, short-tailed shrews, and meadow jumping mice. It is not surprising to find that meadow voles are positively associated with cover values on pasture sites. However, while there is a positive relationship between cover variables and vole abundance in non-stream areas, the relationship does not hold immediately next to the stream. Short-tailed shrew abundance also has a stronger, positive association with higher cover levels (particularly with litter depth) in non-stream areas than stream areas. In addition, meadow jumping mice are not closely associated with cover levels in stream areas. Furthermore, although litter depth is believed to be positively associated with abundance of meadow voles and shrews, I found these species to prefer stream areas despite the reduced litter layer next to the stream compared to away from the stream. Therefore, meadow voles, short-tailed shrews and meadow jumping mice are likely to be attracted to stream areas on pastures for reasons other than favorable vegetation.

Getz (1970) suggested that although cover was important, wet substrate was the most critical environmental factor influencing the abundance of meadow voles. My results support Getz's finding that soil moisture or other characteristics of stream areas preempt cover as a critical habitat requirement for meadow voles. My results suggest that this may be true for short-tailed shrews and meadow jumping mice as well. However, the specific qualities associated with soil moisture and/or stream areas that influence meadow vole, as well as short-tailed shrew and meadow jumping mouse abundance remains unknown.

Thirteen-lined ground squirrels prefer well drained soils and showed an opposite trend than was observed in species that prefer moist soils. In this study, this species follows its expected negative relationship with cover only in stream areas. Again, it may be that cover is important for this species only when it is found away from more critical environmental characteristics associated with dry areas.

Stream-side investigation

It is not surprising that the highest cover values are found on buffer sites, and it appeared that these cover values occur above the threshold level for meadow voles where variability in cover levels have no impact on abundance for this species. This result supports the relationship between cover and meadow vole abundance proposed by Birney et al. (1976). The same relationship was found for all species combined, although this result was probably driven by the dominance of meadow voles in stream-side small mammal communities. I also found evidence that this relationship may also describe the relationship between vegetation-height-density and short-tailed shrew and meadow jumping mouse abundance. However, for these species, the correct model describing the relationship between litter depth and abundance is unclear. In fact, it may be that the litter depth values on pastures lie before threshold I (Fig. 1) and litter depth values from buffer sites lie after threshold II (Fig. 1) in the hypothesized relationship between cover values and species abundance. If this is the case, then I would expect small mammal variables to be higher for cover levels of buffer sites than cover levels of pasture sites. However, within these groups I would expect small mammal abundance to remain constant as cover levels increase (Fig. 14). Therefore, it appears that the relationship between cover and abundance for short-tailed shrews and meadow jumping mice is positive, although the specific behavior of this relationship as cover values increase remains unclear.

Results for thirteen-lined ground squirrel suggest that the linear model may not be the best model to fit the data. It may be that a cover threshold exists above which thirteen-lined ground squirrels will not occur, and that cover values on buffer sites fall above this threshold. A model incorporating this threshold may better describe the relationship between cover values and thirteen-lined ground squirrel abundance.

Contrary to results in the pasture investigation as well as the expected habitat requirements of this species, *Peromyscus* spp. had a positive association with vegetation cover in the stream-side investigation. When found in grasslands, *Peromyscus maniculatus* and *Peromyscus leucopus* prefer low cover levels (Jackson 1961), so this result is probably not due to the presence of one species on pastures and the other on buffer strips. This relationship is probably a result of the proximity of buffer strips to suitable habitat associated with crop fields where *Peromyscus* spp. were frequently captured. In fact, it was not uncommon to capture the same individual in both a buffer strip and a crop field. *Peromyscus* spp. are considered habitat generalists (Kaufman et al. 1990) and are known to use "refuges" or separate habitat types within their home range that provide protection from predators (Stickel 1968). *Peromyscus* spp. may be using the buffer strips for predator avoidance, but may be more closely tied to food resources available in adjacent habitats. This result demonstrates the complexity of habitat relationships within a heterogeneous landscape where species may be utilizing resources among spatially segregated and highly distinct habitat types. This also suggests that buffer strips supply an important refuge from predation pressure, perhaps increasing the suitability of agricultural habitats and connecting otherwise isolated populations.

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Table 1. Results from literature review summarizing cover relationship for small mammal species with more than 10 captures.

Small Mammal Variable	**Cover Relationship**	**Stream Relationship**	**Sources**
Meadow vole	Positive, with threshold: litter depth important <10 cm and vegetation height important <10 dm	Associated with moist soils	Peles and Barrett 1996, Grant et al. 1982, Eadie 1953, Snyder and Best 1982.
Short-tailed shrew	Positive, possible threshold: litter depth important	Associated with moist soils	Kurta 1995, Jones et al. 1983.
Masked shrew	Positive, possible threshold: litter depth important	Associated with moist soils	Doyle 1990, Bowles and Copsey 1992
Meadow jumping mouse	Positive, with possible threshold: vegetation height important <100 cm. Litter layer not an important habitat variable	Associated with moist soils, strongly associated with stream areas	Kurta 1995, Jones et al. 1983.
Peromyscus spp.	Negative, linear	Associated with dry soils	Kurta 1995, Jones et al. 1983 Snyder and Best 1980, Furrow 1994
Thirteen-lined ground squirrel	Negative, linear	Associated with dry soils	Kurta 1995, Jones et al. 1983

**Peromyscus maniculatus* prefers open grassy areas and habitats with little cover while *Peromyscus leucopus* prefers wooded habitats and is less likely to be found in open, grassy areas (Jones et al. 1983). Therefore, models are based on habitat affinities of *Peromyscus maniculatus*.

Table 2. General predictions relating cover variables with small mammal abundances based on literature review in Table 1.

Small mammal Variable	Investigation	Model	Rationale for Hypothesis
Meadow vole, Short-tailed shrew, Masked shrew, all species combined	Pasture	Abundance ~ Constant + Robel	Cover important, but contribution of litter is limited in pastures and is not expected to be important. Moderately to strongly associated with non-vegetation characteristics of stream areas, so relationship to vegetation may be stronger in stream and non-stream areas.
	Stream-side	Abundance ~ Constant + Robel (with threshold)	Vegetation height-density may be the only important cover variable. Vegetation height-density on buffer sites lies above threshold and will be apparent in the analysis.
	Stream-side	Abundance ~ Constant + litter depth (with threshold)	Depth of litter layer may be the only important cover variable. Litter layer depth on buffer sites lies above threshold and will be apparent in the analysis.
Meadow jumping mouse	Pasture	Abundance ~ Constant + Robel	A positive linear relationship with Robel height is expected. Strongly associated with non-vegetation characteristics of stream areas, so relationship to vegetation may be stronger in stream and non-stream areas.
	Stream-side	Abundance ~ Constant + Robel (with threshold)	Cover levels in stream areas of buffer sites fall above threshold level, so relationship is non-linear following the threshold model. Vegetation height-density may be the only important cover variable because this species is not known to prefer a substantial litter layer.
Peromyscus spp., Thirteen-lined ground squirrel	Pasture and Stream-side	Abundance ~ Constant - Robel	Prefers low cover levels and will be negatively correlated with both Robel height and litter depth in stream-side investigation and Robel height along in the pasture investigation. Moderately to strongly associated with dry soils, so relationship to vegetation may be non-stronger than stream areas.

Table 3. Mean cover values (SD) for 1997 and 1998 by treatment and location.

Cover variable	Location	Continuous		MIRG		Buffer	
		1997	1998	1997	1998	1997	1998
Robel height (dm)	Stream	0.6 (0.3)	0.8 (0.3)	1.0 (0.3)	1.2 (0.3)	5.0 (3.0)	6.5 (2.5)
	Non-stream	0.8 (0.6)	0.9 (0.7)	0.9 (0.4)	1.1 (0.3)	----	----
Litter depth (cm)	Stream	2.0 (1.0)	2.2 (1.5)	3.5 (0.6)	2.5 (0.9)	51.7 (7.7)	60.7 (14.3)
	Non-stream	4.4 (3.3)	3.0 (2.4)	6.1 (3.4)	4.9 (3.9)	----	----

Table 4. Results from paired t-tests comparing stream and non-stream results for capture rates for small mammal variables and cover variables.

Variable	**Average Capture Rate in Stream Area (SD)**	**Average Capture Rate in Non-stream Area (SD)**	**p-value**
Meadow vole	25.5 (16.3)	13.6 (10.3)	0.08
Short-tailed shrew	4.3 (3.1)	1.2 (1.8)	0.01
Masked shrew	0.74 (1.6)	2.1 (2.8)	0.11
Meadow jumping mouse	3.5 (3.5)	0.0 (0.0)	0.02
Thirteen-lined ground squirrel	1.6 (2.8)	2.8 (4.8)	0.55
Peromyscus spp.	2.3 (4.5)	0.6 (1.6)	0.15
All species	38.4 (18.2)	20.8 (12.3)	0.03

Table 5. Results from models testing the relationship between changes in cover variables and small mammal capture rates between stream and non-stream areas.

Species	**Model**	**R^2**	**P-value**
Meadow vole	Capture rate $_{(S-N)}$ = Constant +Robel height $_{(S-N)}$	.404	.09
	Capture rate $_{(S-N)}$= Constant +litter depth $_{(S-N)}$	.345	.12
	Capture rate $_{(S-N)}$= Constant + Robel height $_{(S-N)}$ +litter depth $_{(S-N)}$	.423	.25
Short-tailed shrew	Capture rate $_{(S-N)}$= Constant + Robel height $_{(S-N)}$	.007	.85
	Capture rate $_{(S-N)}$= Constant +litter depth $_{(S-N)}$	.215	.25
	Capture rate $_{(S-N)}$ = Constant + Robel height $_{(S-N)}$ +litter depth $_{(S-N)}$	.437	.24
Meadow jumping mouse	Capture rate $_{(S-N)}$ = Constant + Robel height $_{(S-N)}$	.100	.44
	Capture rate $_{(S-N)}$ = Constant + litter depth $_{(S-N)}$	.043	.62
	Capture rate $_{(S-N)}$ = Constant + Robel height $_{(S-N)}$ +litter depth $_{(S-N)}$	X	X
All species	Capture rate $_{(S-N)}$ = Constant + Robel height $_{(S-N)}$	.188	.28
	Capture rate $_{(S-N)}$ = Constant +litter depth $_{(S-N)}$	.376	.10
	Capture rate $_{(S-N)}$ = Constant + Robel height $_{(S-N)}$ −litter depth $_{(S-N)}$	.376	.11

X = Model did not converge.

All coefficients are positive.

Table 6. Results from test of the relationship between cover variables and small mammal variables in stream and non-stream areas on pasture sites.

Species	**Model**	**Relationship**	**Stream**		**Non-stream**	
			Sq.multiple R	**Pvalue**	**Sq. multiple R**	**P-value**
Meadow vole	Capture rate = Constant + Robel height	Positive	.007	.849	.549	.04
	Capture rate = Constant + Litter depth	Positive	.137	.366	.643	.02
	Capture rate = Constant + Robel + Litter depth	Positive	.156	.65	.654	.07
Short-tailed shrew	Capture rate = Constant + Robel height	Positive	.075	.51	.201	.26
	Capture rate = Constant + Litter depth	Positive	.010	.82	.301	.16
	Capture rate = Constant + Robel + Litter depth	Positive	.079	.82	.302	.41
Masked shrew	Capture rate = Constant + Robel height	Positive	X	X	.002	.92
	Capture rate = Constant + Litter depth	Positive	X	X	.172	.31
	Capture rate = Constant + Robel + Litter depth	Positive	X	X	.526	.15
Meadow jumping mouse	Capture rate = Constant + Robel height	Positive	.313	.15	X	X
	Capture rate = Constant + Litter depth	Positive	.240	.22	X	X
	Capture rate = Constant + Robel + Litter depth	Positive	.365	.32	X	X

(Table 6 cont.)

Table 6. (Continued).

Species	Model	Relationship	Stream		Non-stream	
			Sq.multiple R	Pvalue	Sq. multiple R	P-value
Thirteen-lined ground squirrel	Capture rate = Constant - Robel height	Negative	.470	.06	.029	.68
	Capture rate = Constant - Litter depth	Negative	.593	.03	.002	.92
	Capture rate = Constant + Robel height + Litter depth	Negative	.701	.05	.068	.84
Peromyscus spp.	Capture rate = Constant - Robel height	Negative	.543	.04	X	X
	Capture rate = Constant - Litter depth	Negative	.213	.25	X	X
	Capture rate = Constant - Robel height + Litter depth	Negative	.551	.14	X	X
All Species	Capture rate = Constant + Robel height	Positive	.011	.80	.431	.08
	Capture rate = Constant - Litter depth	Positive	.060	.56	.582	.03
	Capture rate = Constant + Robel height + Litter depth	Positive	.136	.69	.582	.11

X= Analysis not run due to low sample size.

Table 7. Results from linear and non-linear models relating cover variables to small mammal variables from stream-side areas.

Species	Model	Relationship	Linear Model R^2	Linear Model Pvalue	Non-linear Model R^2	Non-linear Model Pvalue	Best Fit
Meadow vole	Capture rate = Constant + Robel height	Positive	0.309	0.06	0.283^a	0.07	Non-linear
	Capture rate = Constant + Litter depth	Positive	0.319	0.06	0.331^a	0.07	Non-linear
Short-tailed shrew	Capture rate = Constant + Robel height	Positive	0.665	0.001	0.759	0.09	Non-linear
	Capture rate = Constant + Litter depth	Positive	0.722	0.000	0.752	0.09	Linear
Meadow jumping mouse	Capture rate = Constant + Robel height	Positive	0.487	0.01	0.617	0.11	Non-linear
	Capture rate = Constant + Litter depth	Positive	0.498	0.01	0.605	0.11	Linear
Thirteen-lined ground squirrel	Capture rate = Constant + Robel height	Negative	0.170^a	0.43	X	X	---
	Capture rate = Constant + Litter depth	Negative	0.161^a	0.20	X	X	---
Peromyscus spp.	Capture rate = Constant + Robel height	Positive	0.612	0.003	X	X	---
	Capture rate = Constant + Litter depth	Positive	0.607^a	0.003	X	X	---
All species	Capture rate = Constant + Robel height	Positive	0.658	0.001	0.534	0.07	Non-linear
	Capture rate = Constant + Litter depth	Positive	0.702	0.001	0.612	0.06	Non-linear

^{a}= Problems with residual plots (Figs. 7,8,13).

X = Analysis not conducted.

Figure 1. Threshold hypothesis suggested by Snyder and Best 1982, Peles and Barrett 1996, Birney et al. 1976.

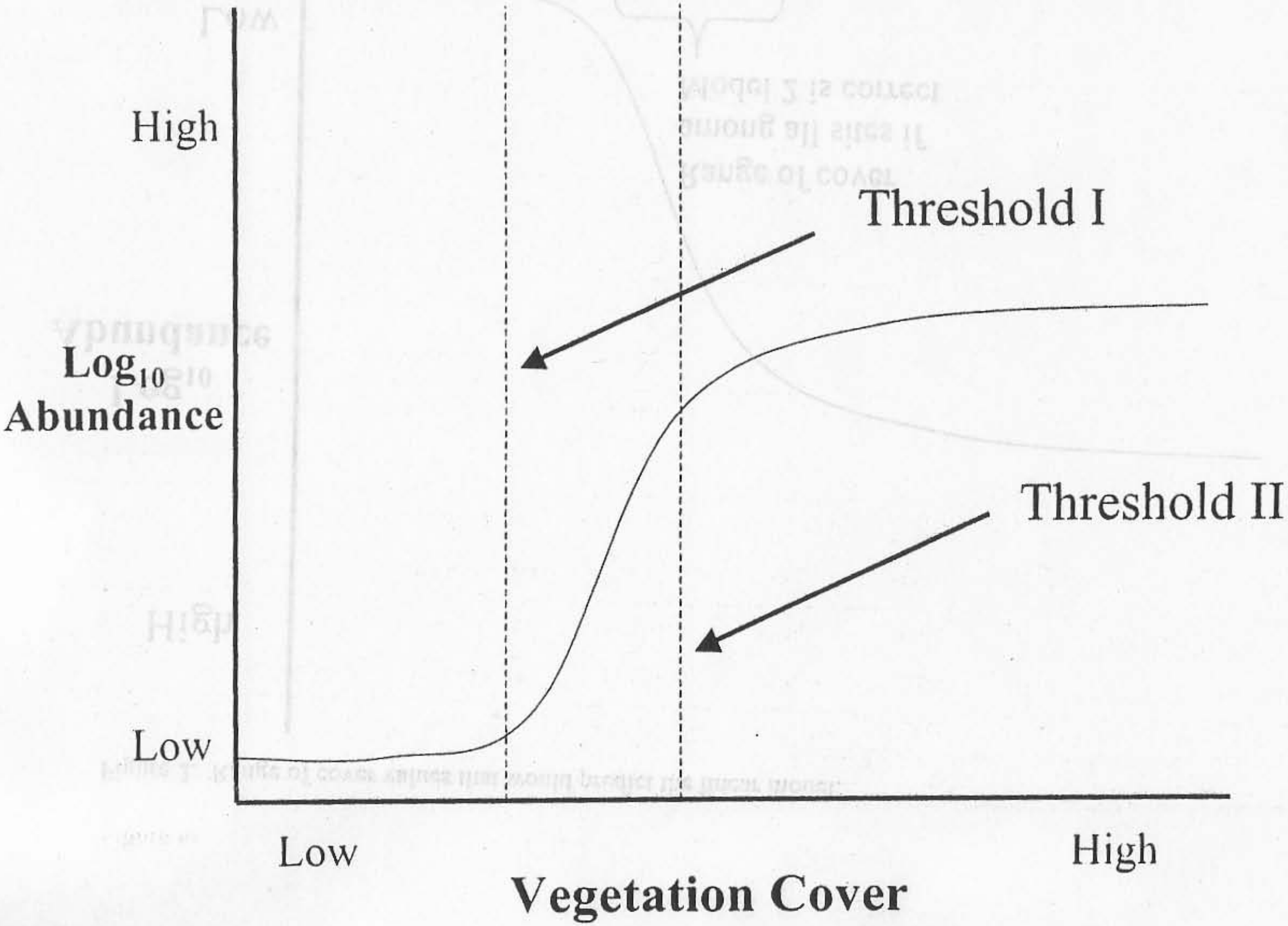


Figure 2. Range of cover values that would predict the linear model.

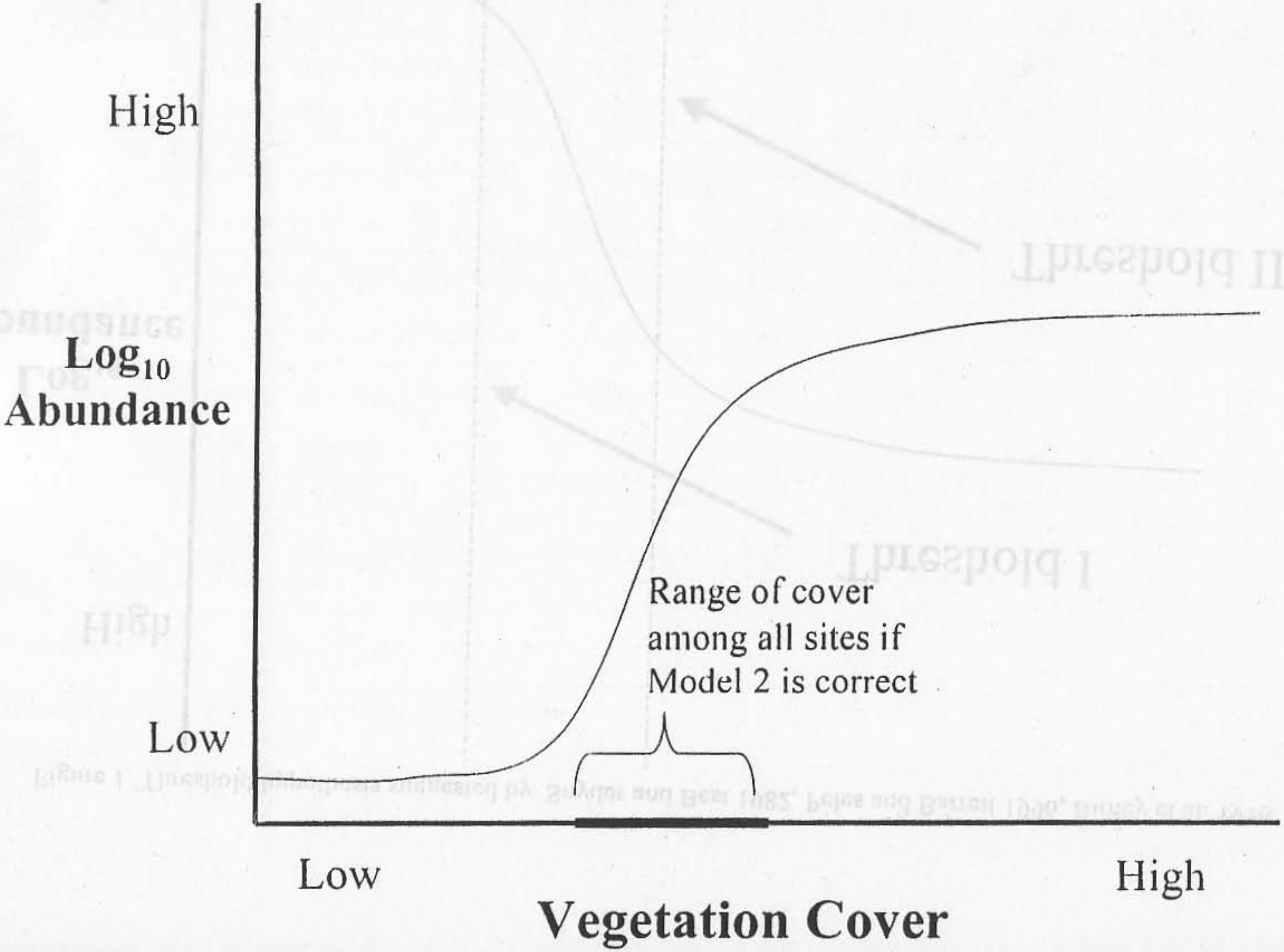


Figure 3. Linear model: $\text{Abundance} = m\,(\text{Vegetation variable}) + b$, where b is the slope of the line and m is the Y intercept.

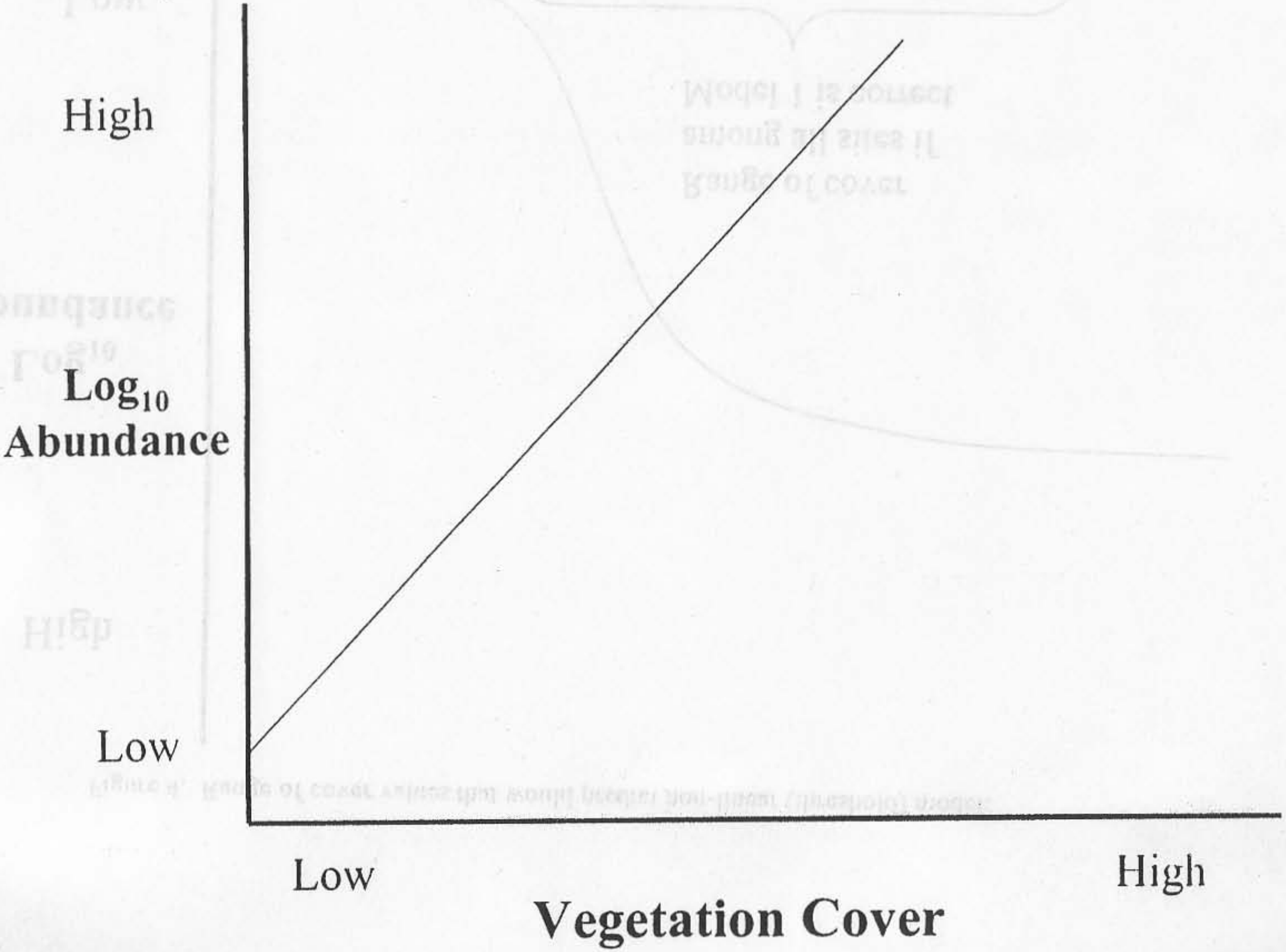


Figure 4. Range of cover values that would predict non-linear (threshold) model.

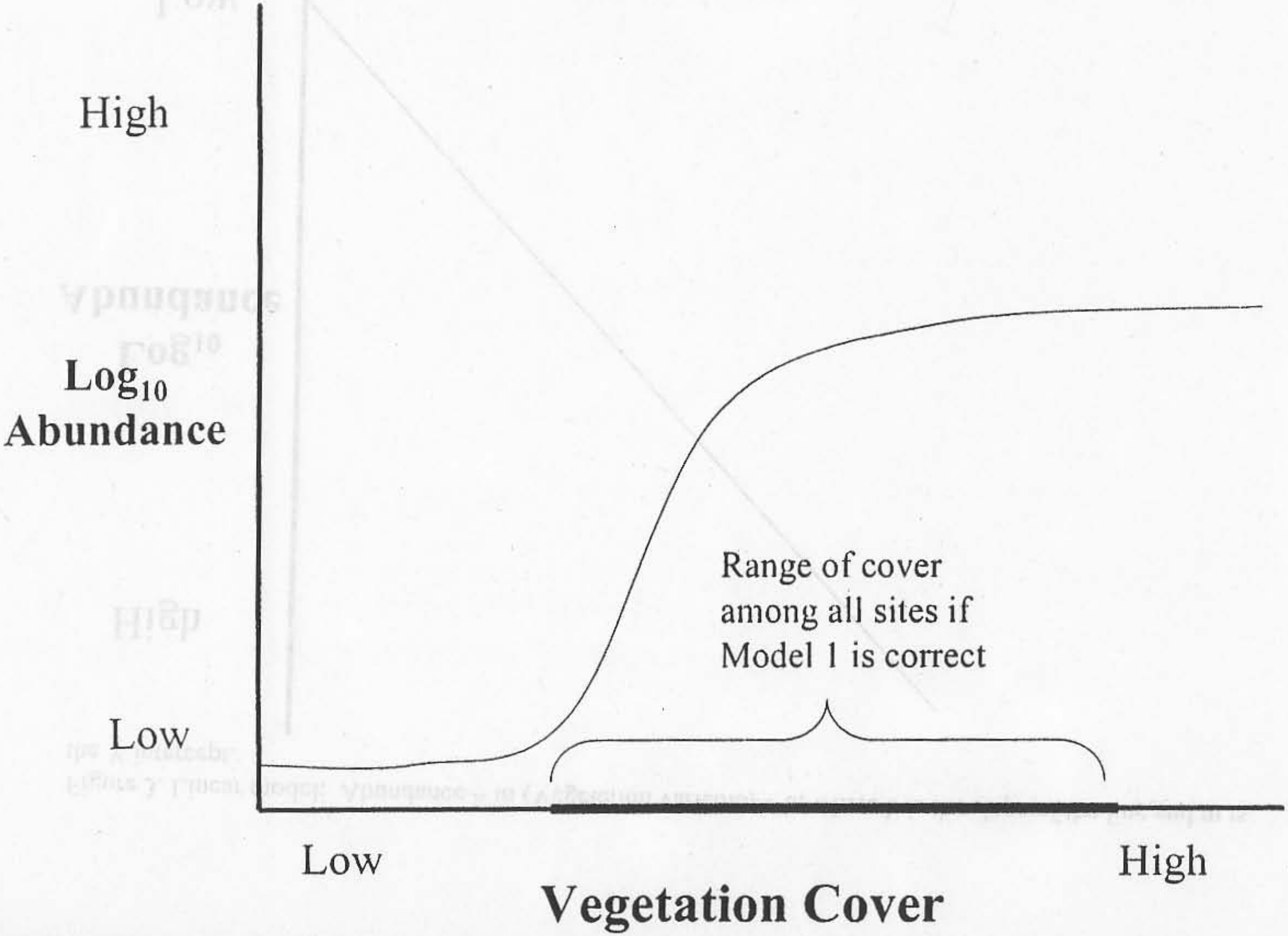


Figure 5. Non-linear (threshold) model: Abundance = a $(1 - e^{-\text{vegetation variable} * (b)})$

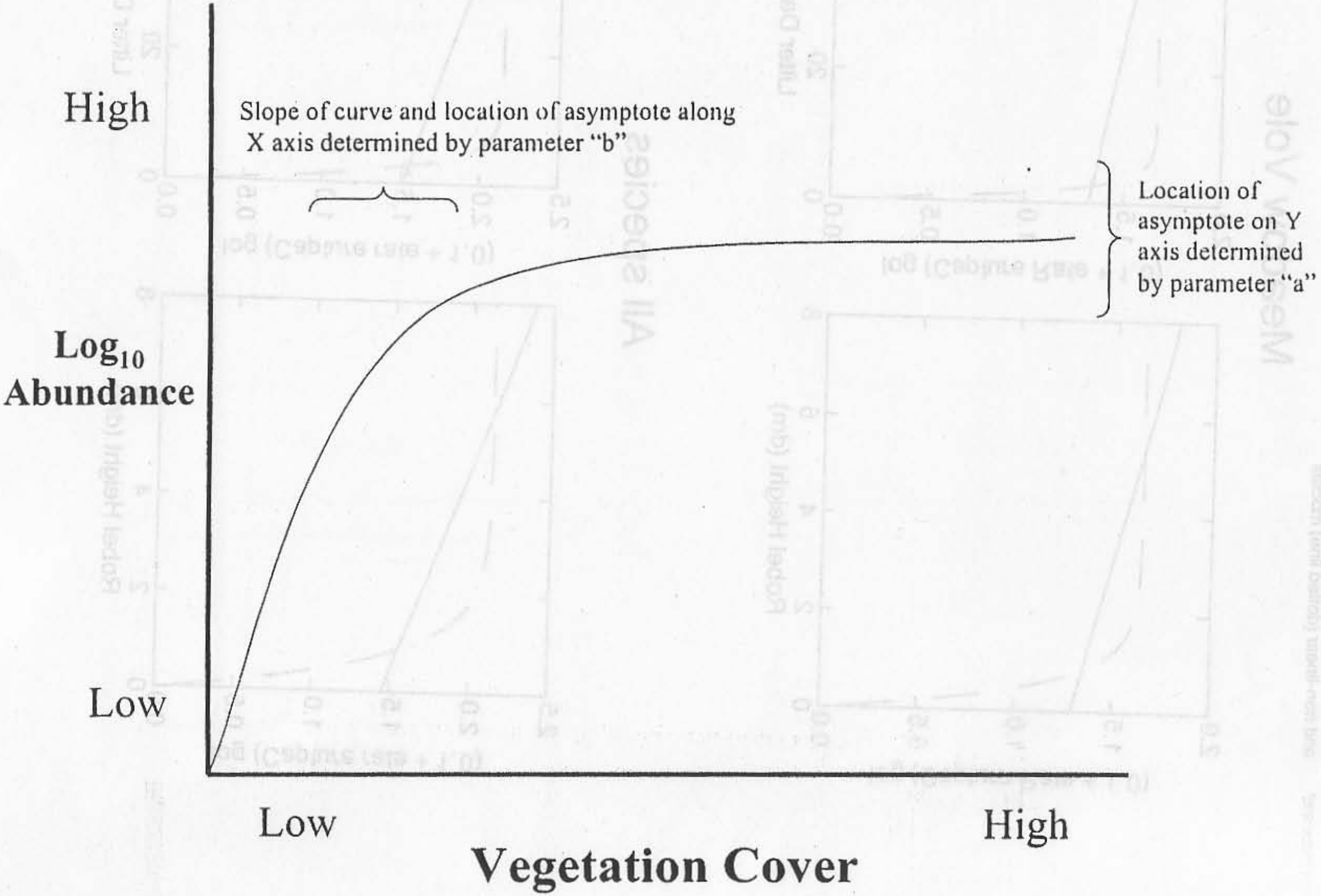
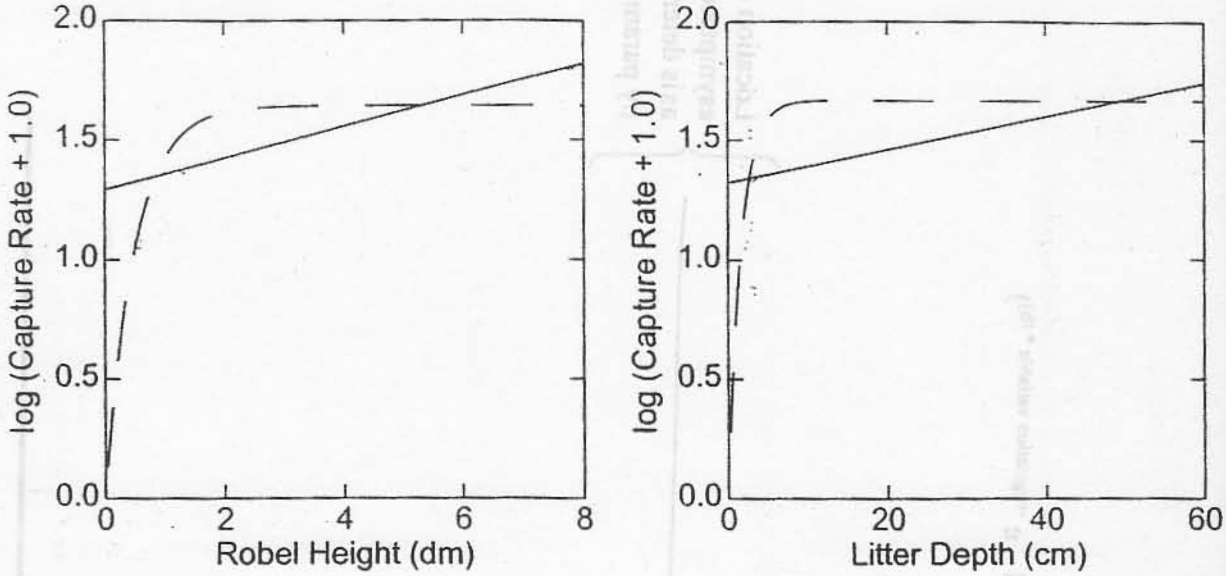


Figure 6. Capture rates plotted against cover variable values with fitted linear (solid line) and non-linear (dotted line) models

Meadow Vole



All species

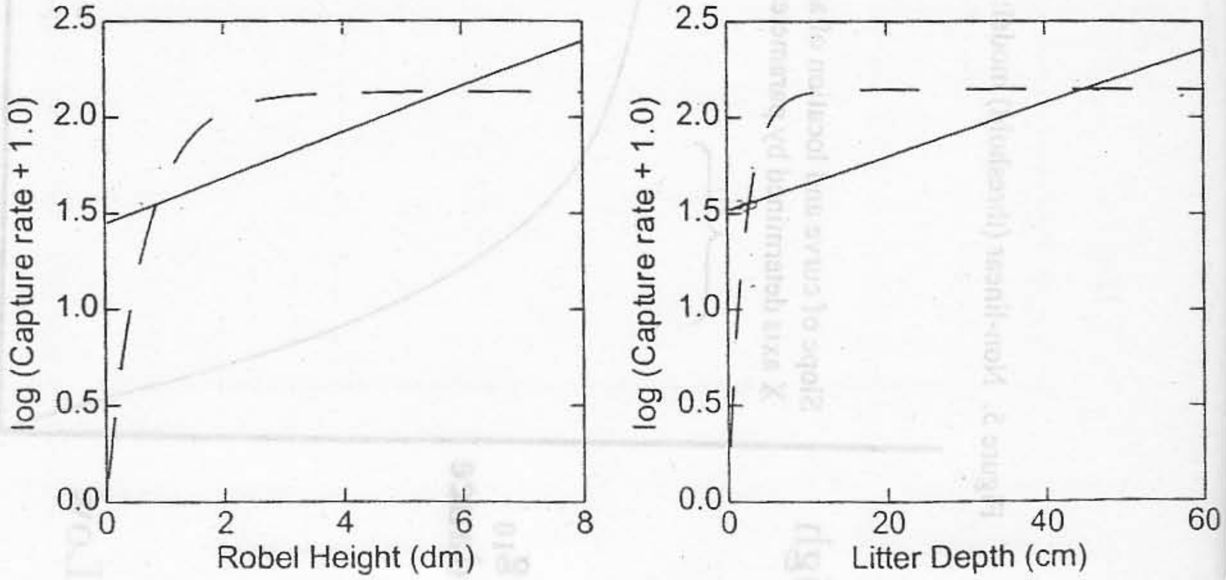
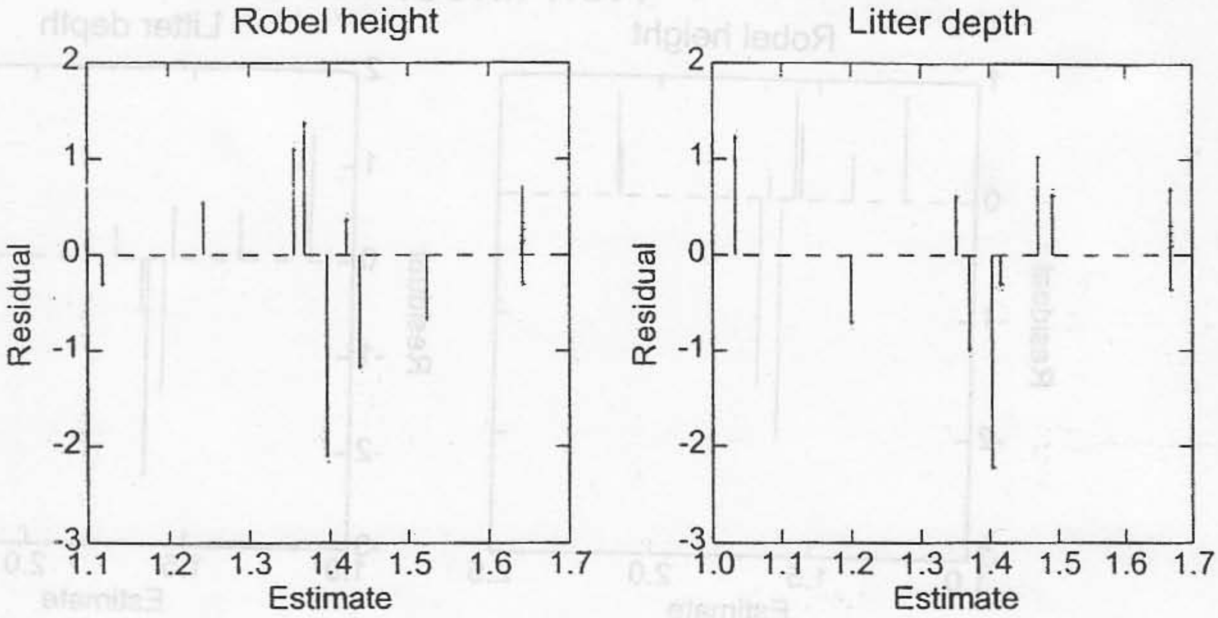


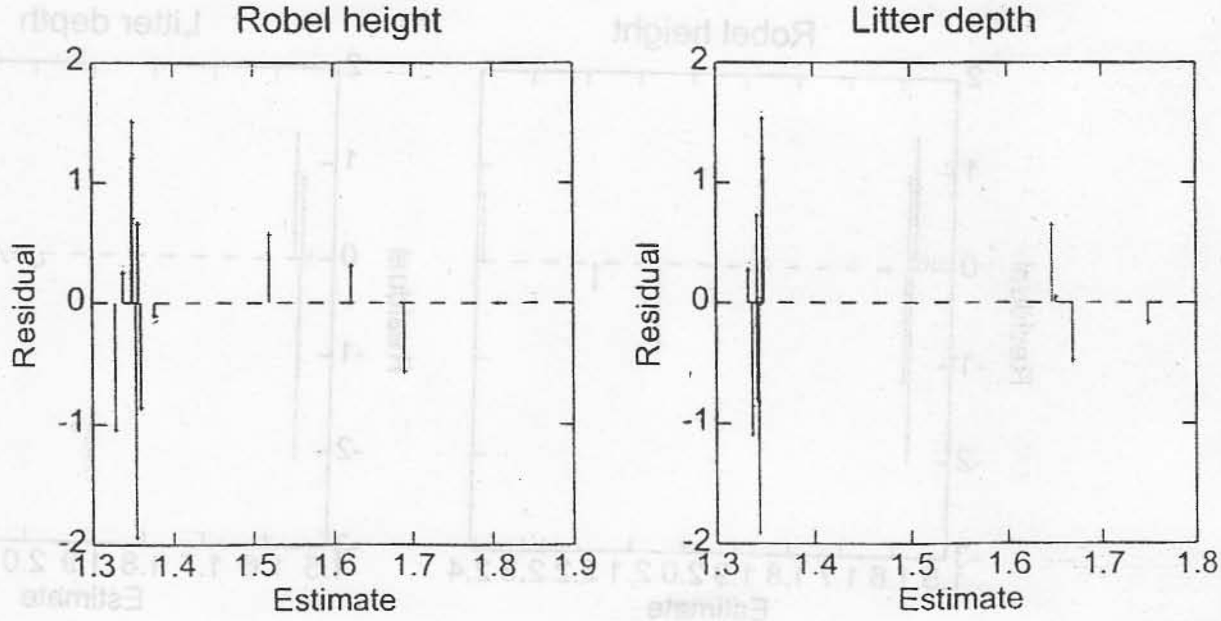
Figure 7. Residual plots for Meadow vole linear and non-linear comparisons

Non-linear Model


Robel height

Litter depth

Linear Model


Robel height

Litter depth

Figure 8. Residual plots for All Species linear and non-linear comparisons

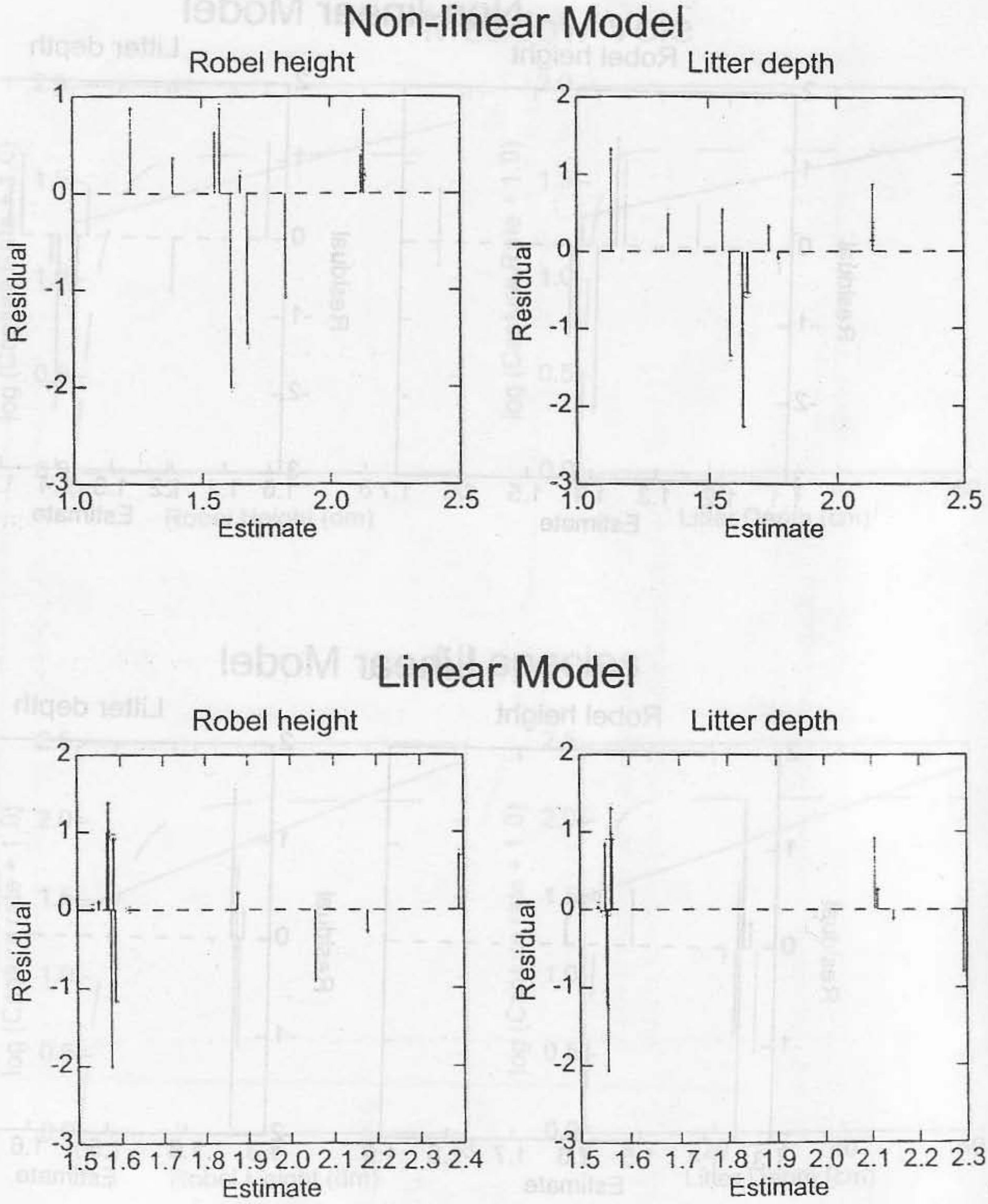
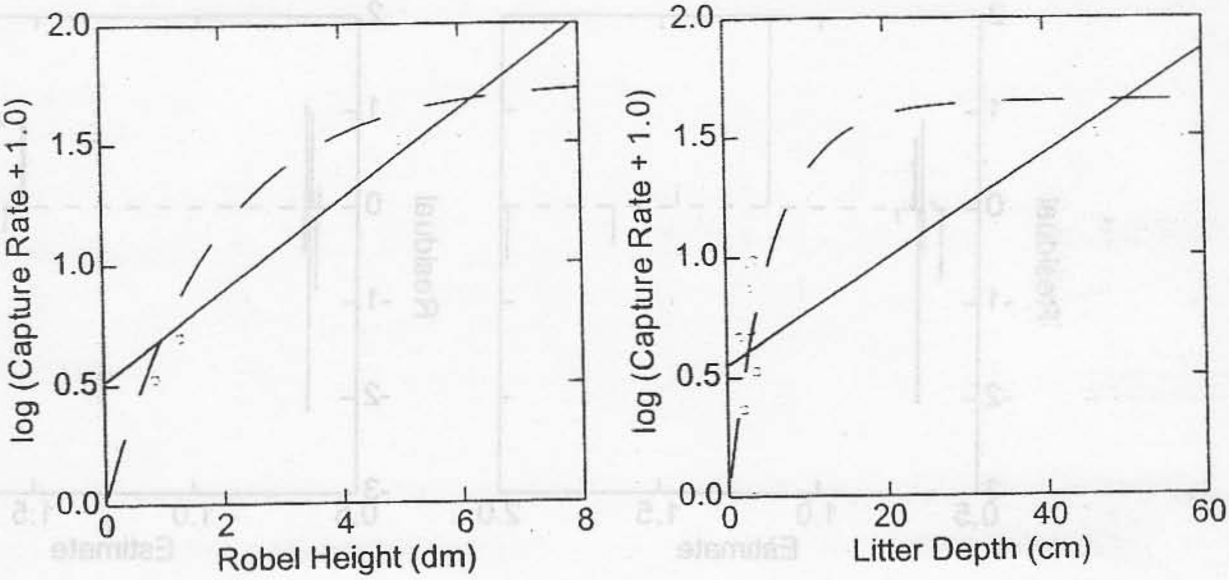


Figure 9. Capture rates plotted against cover variable values with fitted linear (solid line) and non-linear (dotted line) models

Short-tailed shrew



Meadow jumping mouse

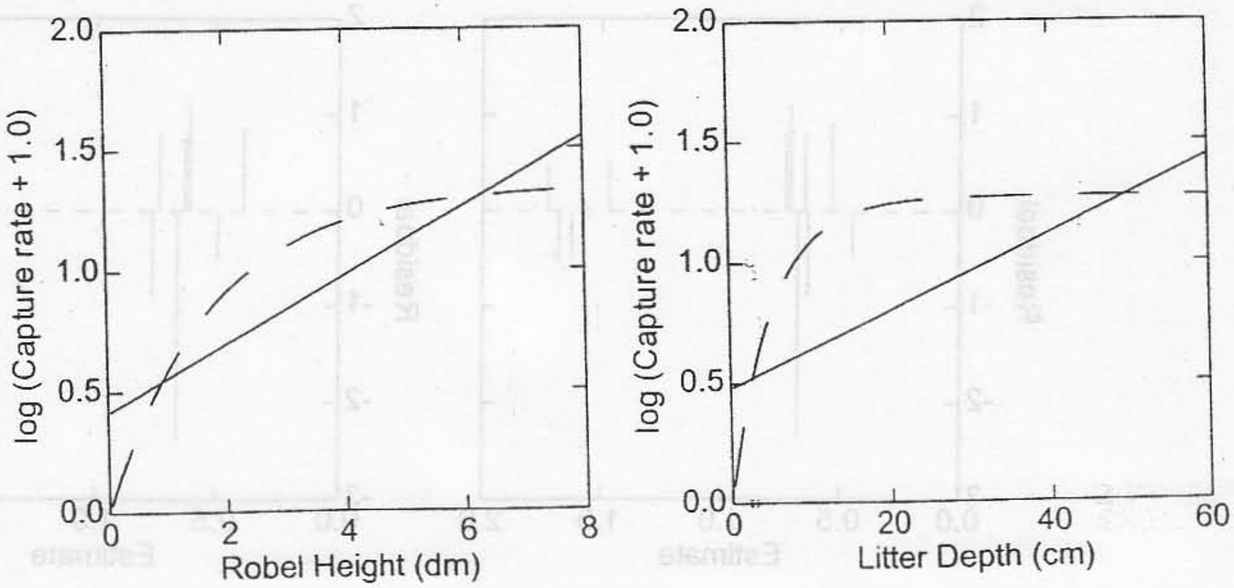


Figure 10. Residual plots for Short-tailed shrew linear and non-linear models

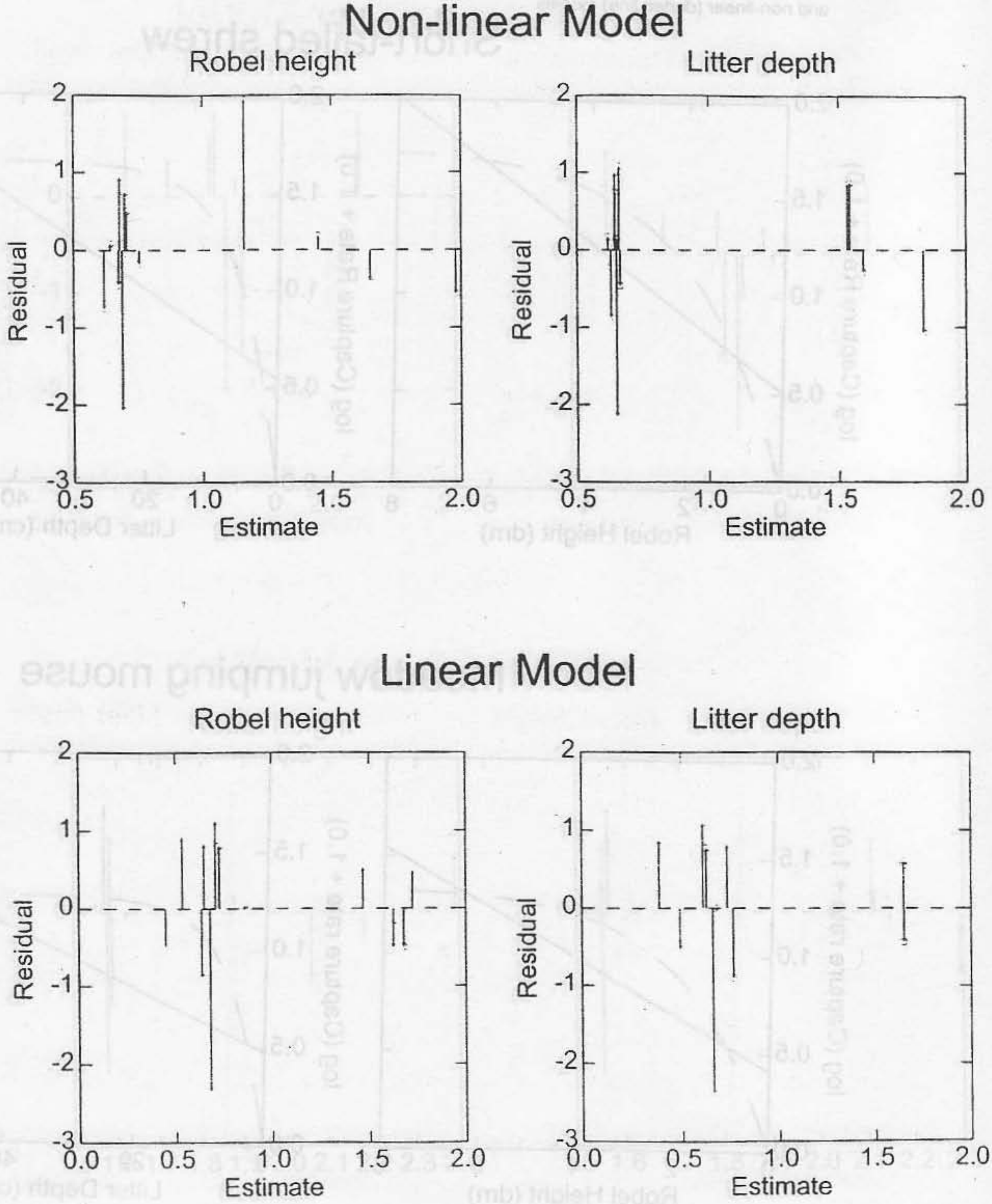


Fig. 11. Residual plots for Meadow jumping mouse linear and non-linear models

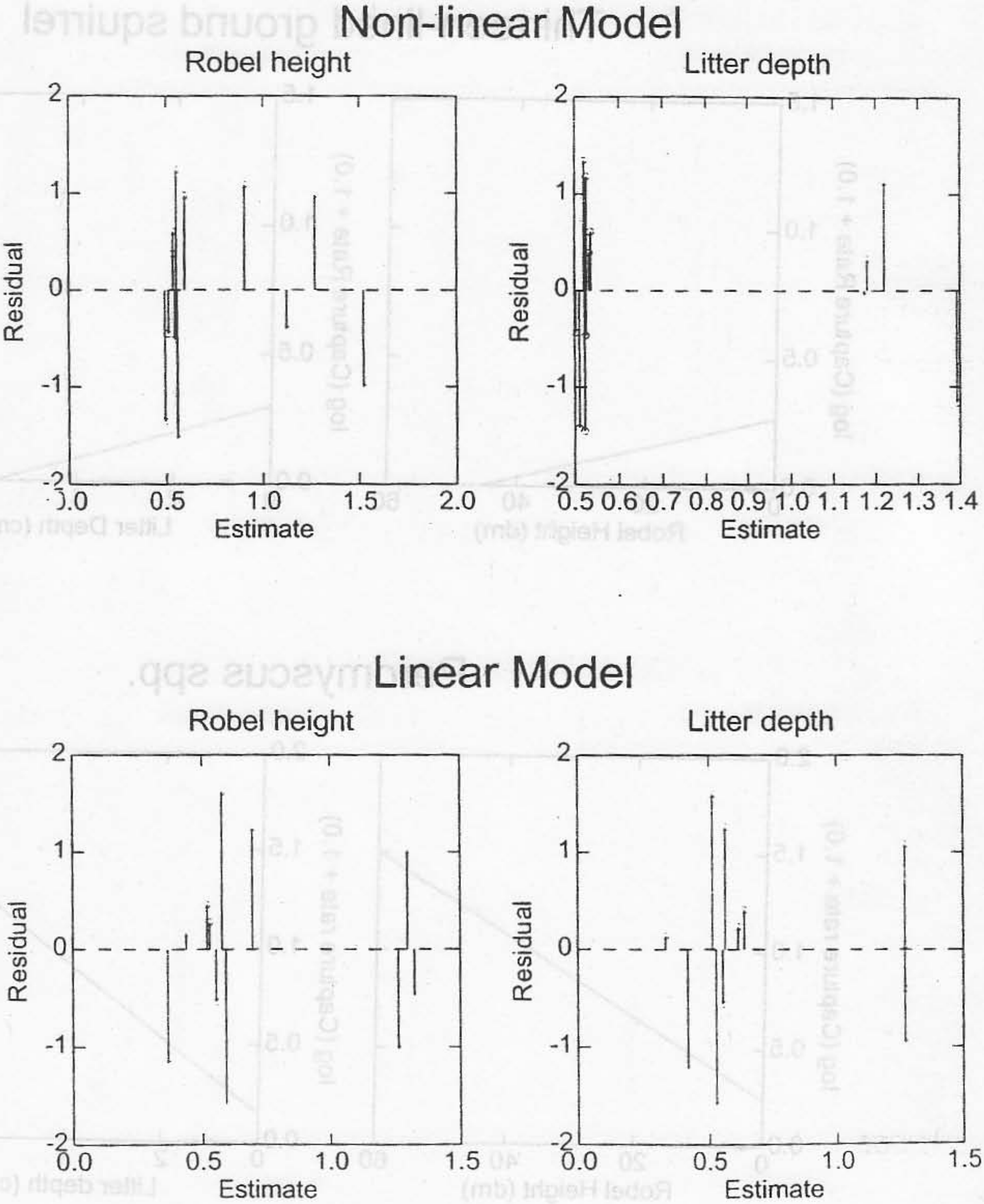


Figure 12. Capture rates plotted against cover variable values with fitted linear (solid line) and non-linear (dotted line) models

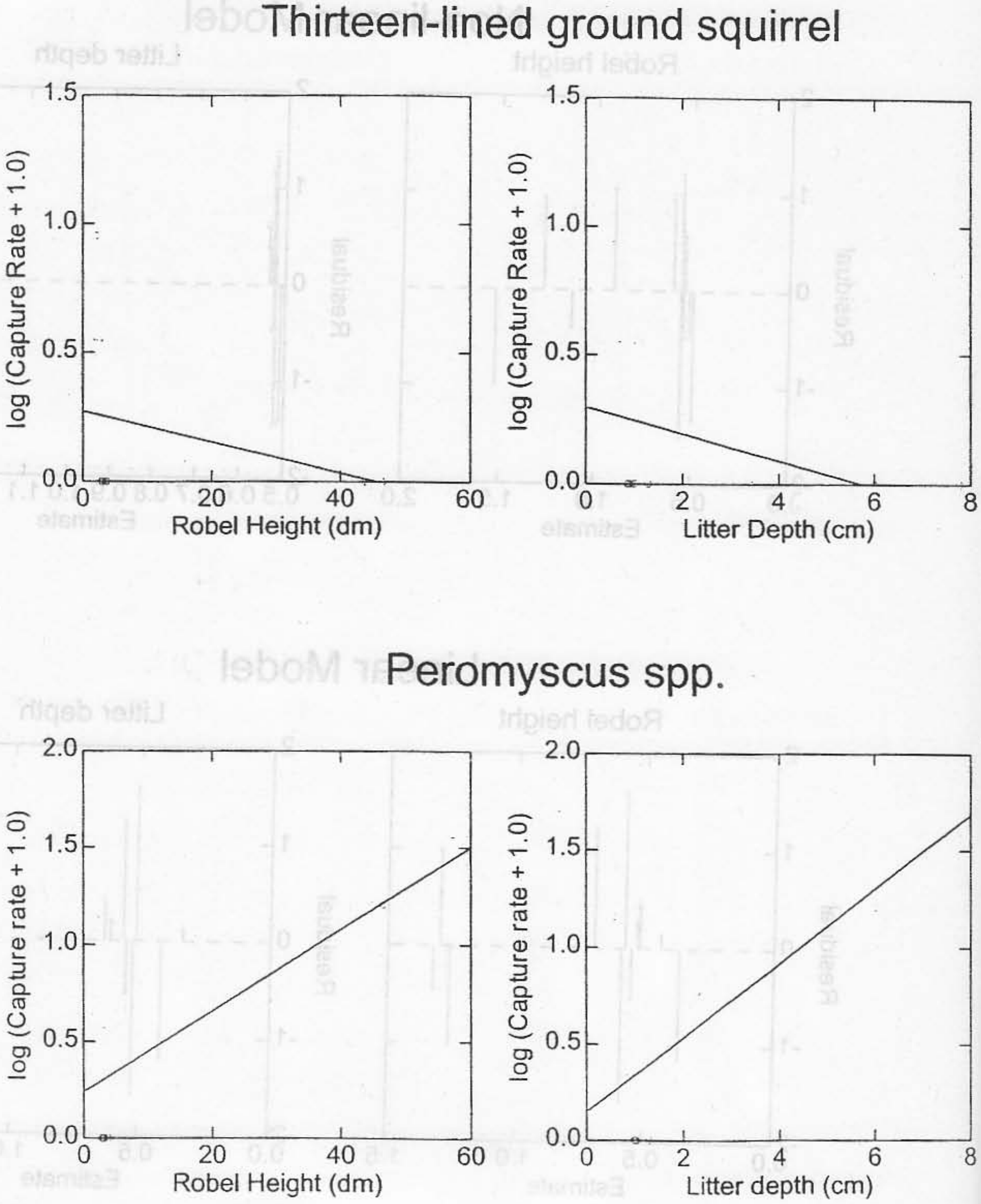


Fig. 13. Residual plots for Thirteen-lined ground squirrel and Peromyscus spp. linear models

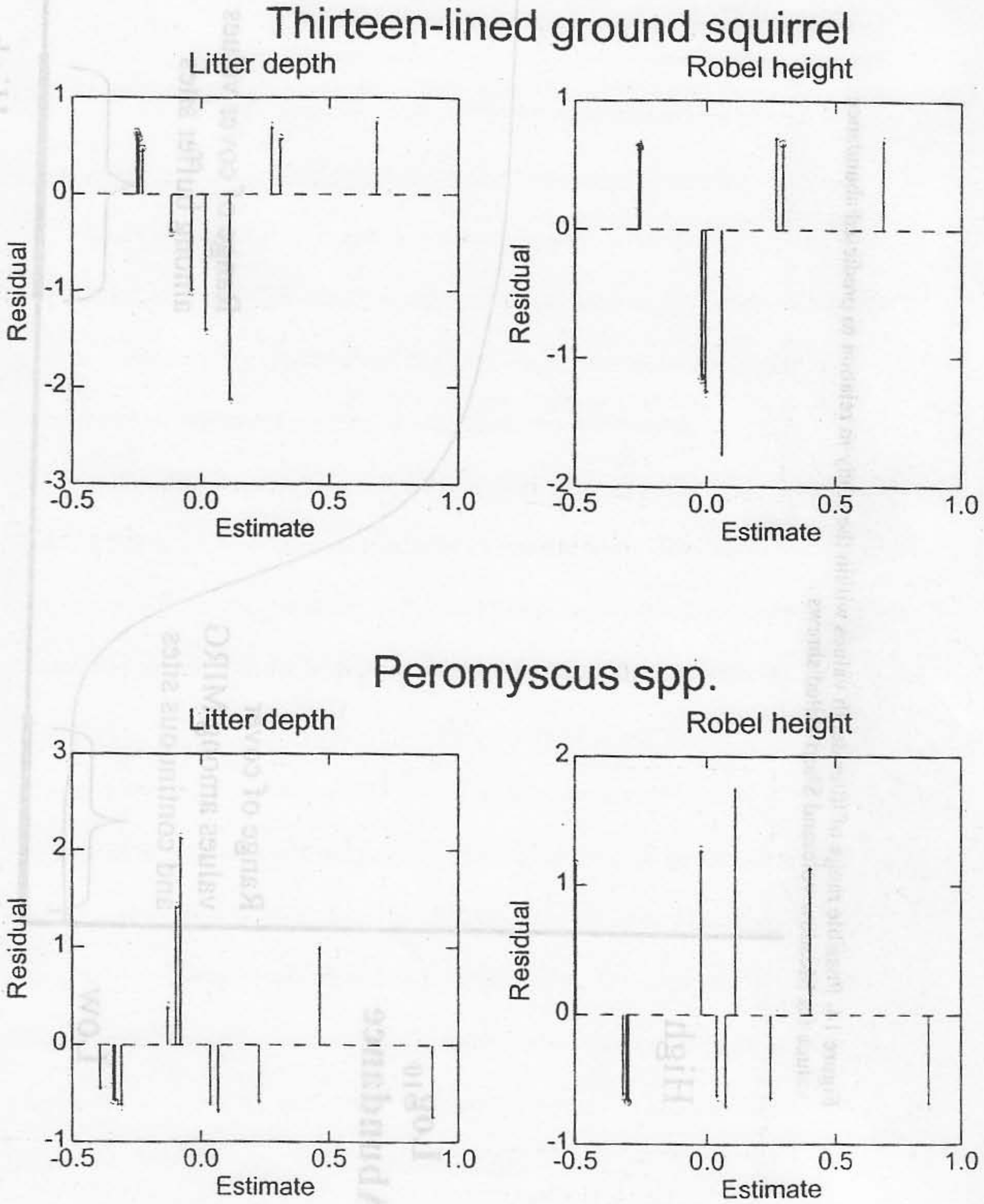
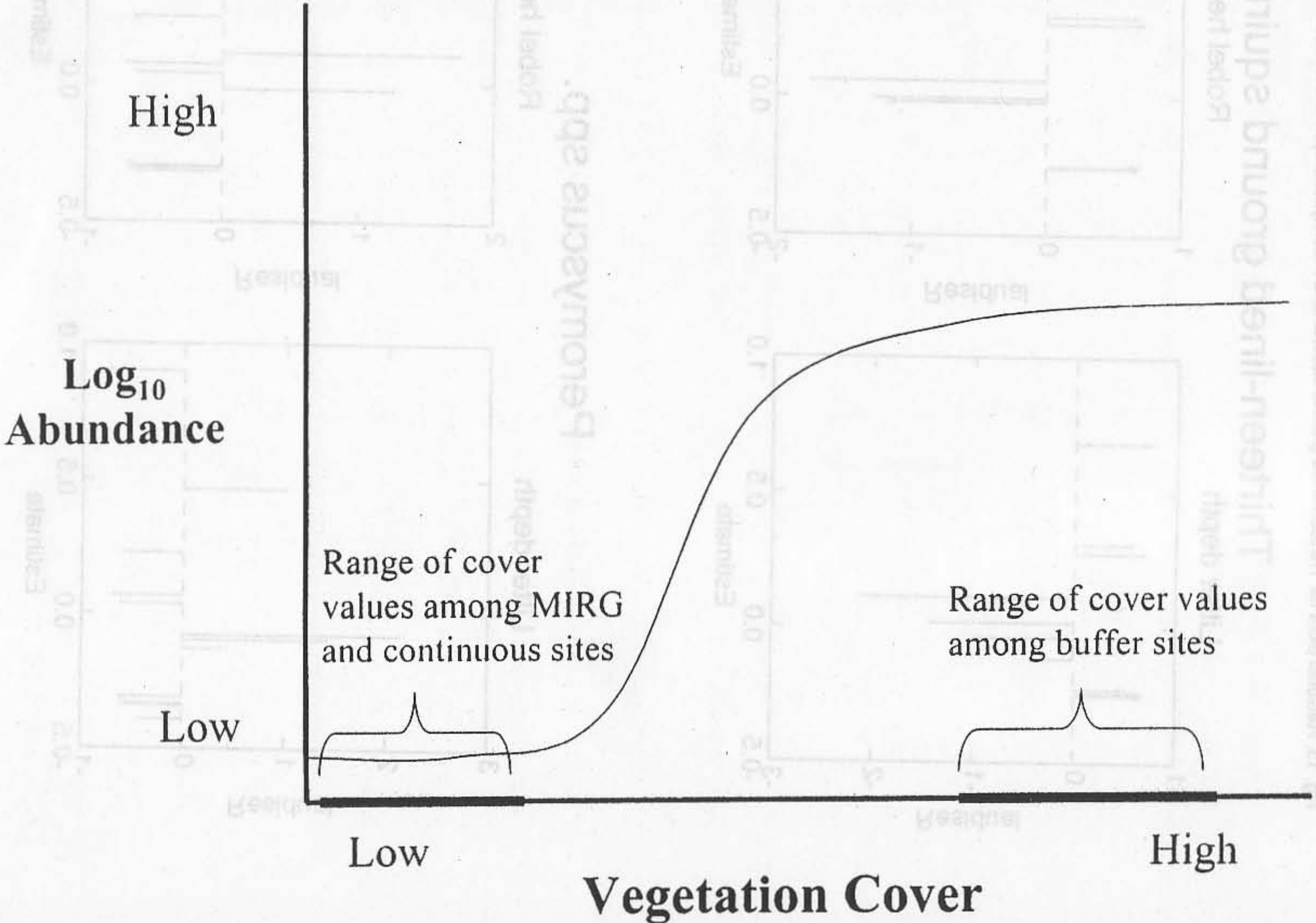


Figure 14. Possible range of litter depth values within the study in relation to predicted abundance values for Meadow volesand Short-tailed shrews .



GENERAL DISCUSSION

Cover and grassland small mammals in southwestern Wisconsin

Influence of grazing induced changes in the small mammal community

Grant et al. (1982) suggested that grazing-induced reduction in cover has a more profound influence on small mammal communities in high-cover grasslands than in other types of grasslands. He hypothesized that there would be a reduction in small mammal biomass and an increase in diversity as vegetation cover decreased.

Buffer strips represent high-cover grassland, whereas pasture sites were characterized by two different patterns of grazing induced cover reduction. My data support the first component of Grant's hypothesis: 1) Although I did not analyze biomass data, it appears that there is greater biomass in the vegetative buffer strips than in stream areas of pastures sites. However, I did not find greater diversity in the low-cover pastures sites. Although a diversity index was not calculated for stream areas alone, greater richness, abundance, and evenness of communities on buffer strips compared to those on pastures suggests diversity is greater in high-cover buffer strips. This difference is correlated with differences in cover provided by buffer strips and pasture sites in this study. Consequently, my results did not support Grant's hypothesis that grazing pressure would increase diversity in high cover grasslands. I suggest that the influence of grazing induced changes in high-cover grasslands depends on the local grassland small mammal community.

Importance of cover on pasture sites

The variability of cover values found on pasture sites appeared to have a strong influence on small mammal abundances in 1998. Litter depth and vegetation-height-density are both structural components that can be influenced by pasture management. Haying, stocking rates, and pasture location, and seasonal changes in livestock management all immediately influence vertical density of vegetation on a farm. These factors then influence the amount of dead vegetation in subsequent years as unutilized forage dies and remains on the ground. Therefore, my results suggest that within the variability that exists among pasture management practices, there are farm management styles that provide vegetation structures that can be important for small mammals.

Year effect

Small mammal communities in North American grasslands are highly variable from year to year (Grant and Birney 1979). I observed an increase in abundance, richness and diversity on all three treatments from 1997 to 1998. This increase occurred across all treatments for several grassland species and probably represents a regional increase in grassland small mammal population sizes. When small mammals experience regionally high population densities, individuals of some species may be crowded out of preferred habitat into lower quality habitat (Getz 1985). This dynamic is called "mass effect," and it is enhanced in a heterogeneous landscape where species occurrence often depends on population dynamics associated with adjacent habitats (Shmida and Wilson 1985). Mass effect appeared to be a factor determining small mammal communities observed in crop-lands on buffer sites. When densities of small mammals were high in buffer strips in 1998, species that were common in buffer strips began to appear more frequently in crop-land.

Mass effect may also explain the increase in small mammal richness and abundance on pasture sites.

Pastures experienced a particularly dramatic increase in 1998 from very few animals and species in 1997. However, richness and abundance also increased on buffer strips, suggesting that this habitat was not saturated during 1997. Pasture sites gained an average of over 3 species while buffer sites gained less than 2. Short-tailed shrews were new to 6 pasture sites, masked shrews were new to 3, and meadow jumping mice, *Peromyscus* spp., meadow voles were new to 2 pasture sites in 1998. All of these species are probably very common in the agricultural landscape enabling them to colonize secondary habitats from adjacent areas. Therefore, pastures may function as secondary habitat for small mammal species during high productivity years in southwestern Wisconsin when the presence of species in pasture communities largely depends on small mammal populations in adjacent habitats.

Results from the analyses conducted in chapter II reflect the relationship between vegetation structure and small mammal abundance presumably during regionally high population densities of grassland small mammals. It is likely that the relationship between small mammal abundances and vegetation structure depends on regional abundances. In 1997, pastures had similar vegetative structure, but supported fewer species and animals than in 1998.

Nevertheless, my results highlight the importance of cover for grassland small mammal species in southwestern Wisconsin. Vegetation-height-density appears to be a very tenuous resource on pasture sites, particularly on MIRG pastures where vegetation growth cycles provide cover on a temporary basis. These growth cycles are probably similar to those seen on hayed fields where forage is grown and harvested several times during each growing season. Vegetation height on continuous sites also varied over the course of the summer, although this variability is less than that which occurs on MIRG pastures. Getz (1971) found that meadow voles remained within an area following mowing. Subsequently, he observed a sharp decline in the meadow vole population resulting from what he suggested was increased predation pressure by avian predators. Therefore, the mediating effect of cover between predation pressure and small mammal populations may be constantly in flux on pastures. Pastures, particularly on MIRG sites, may provide only temporary protection from predators. This, in addition to the generally low vegetation-height-density on pastures, may make pastures important areas for avian and mammalian small mammal predators. Further research is necessary to investigate the complex relationship between cover and small mammal populations on pastures.

Management implications

Rotational pasture trend

The percentage of farmers using MIRG systems has been increasing steadily since the early 1990s. Between 1993 and 1995, the percentage of grazers in Wisconsin that reported using fully MIRG systems increased from 7.2% to 14% (Jackson-Smith et al. 1996). This trend is expected to continue, particularly if MIRG practices are found to reduce livestock damage to stream habitats by traditional livestock management practices. This study does no suggest that a conversion from continuous to MIRG practices will have a meaningful influence on small mammal communities directly. However, farm-wide implications of the conversion may impact small mammals. Conversion to MIRG practices involves a switch from a reliance on grain to grass production for feeding cattle. This often involves a conversion of farmland from cultivation of corn or soybean to pasture land. MIRG pastures provide habitat suitable to more small mammal species than cultivated fields. As a result, the conversion from crop land to MIRG pasture will provide habitat for more small mammal species. Species like thirteen-lined ground squirrels, *Peromyscus* spp., meadow voles and meadow jumping mice are likely to benefit from this landscape trend. Even if riparian pastures represent demographic "sinks" for many of these species, their existence may contribute to meta-population size and stability (Howe and Davis 1991).

Buffer strip trend

In many areas of the country, including southern Wisconsin, Federal government programs are paying farmers to establish buffer strips in riparian areas. These types of programs will increase the prevalence of buffer strips in the landscape. My results suggest that this trend would provide habitat for a broad range of small mammals, benefitting species such as meadow voles, short-tailed shrews, masked shrews, meadow jumping mice, *Peromyscus* spp., and western harvest mice, a species of special concern in Wisconsin. Furthermore, buffer strips appear to be used by species that also use adjacent habitats, perhaps acting as a refuge from predation pressure. Therefore, buffer strips may be improving the quality of adjacent habitats for small mammal species.

Buffer strips provide habitat along stream corridors in southwestern Wisconsin. Stream corridors in highly fragmented landscapes, such as southern Wisconsin, connect and interface with multiple habitat components. This may increase connectivity within the landscape and facilitate ecological and genetic exchange between otherwise isolated habitats (Noss 1983, Gregory et al. 1991). In addition, higher population densities are often found in connected patches (La Polla and Barret 1993, Fahrig and Merriam 1985). Corridors may then counter some of the detrimental effects of fragmentation, improving meta-population stability for species that use buffer strips (Simberloff and Cox 1987).

The apparent concentration of activity immediately adjacent to streams suggests that riparian management that affects these areas may have an important impact on small mammal species. It is also clear from our results that riparian management in southwestern Wisconsin that favors MIRG pastures would have a very different impact on small mammal populations than if management favored buffer strips.

Implications for Wisconsin Species of Special Concern

Overall, three Wisconsin Species of Special Concern were captured on pastures in the study. Two prairie voles were captured on pastures. Prairie voles prefer well drained grasslands and moderate cover (Getz 1985) and therefore may be more common in upland pastures. The prairie voles captured in our study may have dispersed into riparian pastures from adjacent upland areas. I also captured one pine vole on a MIRG pasture. Habitat preference for this species is not well understood. Pine voles are believed to prefer well drained woodlands but have also been found to inhabit grassy fields (Lyon 1958). Prairie and pine voles also require large, continuous and relatively stable habitats, while meadow voles can tolerate small, isolated and ephemeral habitats (Getz 1985). Riparian pastures probably favor meadow voles in part because pastures can be small, isolated, and unstable habitats that are characterized by moist soils. I also captured one arctic shrew on a MIRG site in 1998. Although the arctic shrew prefers moist habitats along lake and stream edges (Jones et al. 1983), this species has northern affinities with the edge of its range overlapping only with the site on which we captured the species. My data provide little information on the value of riparian pastures for these species. However, the extremely limited numbers of these species on pastures suggest that riparian pastures in southwestern Wisconsin are of little importance for the prairie vole, arctic shrew, and pine vole. Western harvest mice were captured in relatively large numbers on buffer sites suggesting that these areas may be important for this species and that increased prevalence of buffer strips in the landscape would benefit this species. Western harvest mice were captured in both buffer strips and crop-land and may be capitalizing on resources available in each habitat.

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Appendix A. Specific location of study sites.

Buffer Sites:

Creek	County	Township and Range, Section, Quarter, Sixteenth
Moen	Dane	7N R6E, 35, SW, SE
Dougherty	Green	3N R6E, 19, NE, NE
East Mill	Richland	10N R1W, 17, SW, NE
Skinner	Green	2N R6E, 12, SE, SW

Continuous Sites:

Creek	County	Township and Range, Section, Quarter, Sixteenth
Bushnell	Green	2N R7E, 9, SW, SW
Leggett	Grant	5N R1E, 2, SE, SW
Pecatonica	Iowa	5N R1E, 2, SE, SE
Fennimore Fork	Grant	7N R2W, 36, NW, SE

MIRG Sites:

Creek	County	Township and Range, Section, Quarter, Sixteenth
Rush	Vernon	100N R6W, 18, NW, SW
Church	Vernon	12N R3W, 12, NE, SW
Spring	Columbia	10N R8E, 22, SW, NW
Lowery	Iowa	7N R6E, 6, SE, SE
Jones Branch	Lafayette	4N R1E, 26, SW, SW

Appendix B. Species and number of original captures by site.

Buffer Sites:

Creek	Year	Species (original captures)
Moen	1997	Meadow vole *(Microtus pennsylvanicus)* (13), short-tailed shrew *(Blarina brevicauda)* (2), meadow jumping mouse *(Zapus hudsonius)* (24), *Peromyscus* spp. (1), thirteen-lined ground squirrel *(Spermopholis tridecelineatus)* (2), house mouse *(Mus domesticus)* (1).
	1998	Meadow vole (29), masked shrew *(Sorex cinereus)* (7), short-tailed shrew (27), meadow jumping mouse (34), *Peromyscus* spp. (26), house mouse (2), chipmunk *(Tamias striatus)* (1).
Dougherty	1997	Meadow vole (14), short-tailed shrew (5), *Peromyscus* spp. (48), western harvest mouse *(Reithrodontomys megalotus)* (4), *Mustela* spp. (1), rat *(Rattus norvegicus)* (1).
	1998	Meadow vole (44), masked shrew (6), short-tailed shrew (31), meadow jumping mouse (8), *Peromyscus* spp. (64), western harvest mouse (6), rat (1).
East Mill	1997	Meadow vole (22), masked shrew (7), short-tailed shrew (14), meadow jumping mouse (21), *Peromyscus* spp. (20), western harvest mouse (1).
	1998	Meadow vole (36), masked shrew (5), short-tailed shrew (58), meadow jumping mouse (16), *Peromyscus* spp. (31), western harvest mouse (15), weasel (1).
Skinner	1997	Meadow vole (11), masked shrew (2), short-tailed shrew (1), meadow jumping mouse (7), *Peromyscus* spp. (29).
	1998	Meadow vole (56), masked shrew (12), short-tailed shrew (47), meadow jumping mouse (11), *Peromyscus* spp. (69), western harvest mouse (6), house mouse (12).

(Appendix B cont.)

Appendix B. (Continued).

Continuous Sites:

Creek	**Year**	**Species (original captures)**
Bushnell	1997	Meadow vole (5), meadow jumping mouse (3), *Peromyscus* spp. (2).
	1998	Meadow vole (9), meadow jumping mouse (1), *Peromyscus* spp. (2), house mouse (1), prairie vole *(Microtus ochragaster)* (1).
Leggett	1997	Meadow vole (7), meadow jumping mouse (1).
	1998	Meadow vole (52), masked shrew (1), short-tailed shrew (10), meadow jumping mouse (7), thirteen-lined ground squirrel (2).
Pecatonica	1997	*Peromyscus* spp. (7), thirteen-lined ground squirrel (10).
	1998	Meadow vole (14), short-tailed shrew (1), *Peromyscus* spp. (13), thirteen-lined ground squirrel (7).
Fennimore Fork	1997	Thirteen-lined ground squirrel (1).
	1998	Meadow vole (20), masked shrew (1), short-tailed shrew (3), meadow jumping mouse (1), *Peromyscus* spp. (1), thirteen-lined ground squirrel (9).

(Appendix B cont.)

Appendix B. (Continued).

MIRG Sites:

Creek	**Year**	**Species (original captures)**
Rush	1997	Meadow vole (1), masked shrew (4), meadow jumping mouse (3).
	1998	Meadow vole (29), short-tailed shrew (3), meadow jumping mouse (6).
Church	1997	**Not Sampled**
	1998	Meadow vole (48), masked shrew (10), short-tailed shrew (4), meadow jumping mouse (4), pine vole *(Pitymys pinetorum)* (1).
Spring	1997	Meadow vole (10), masked shrew (1), thirteen-lined ground squirrel (6).
	1998	Meadow vole (22), masked shrew (4), short-tailed shrew (6), thirteen-lined ground squirrel (10), *Mustela* spp. (1).
Lowery	1997	Meadow vole (8).
	1998	Meadow vole (54), masked shrew (3), short-tailed shrew (8), meadow jumping mouse (3), *Peromyscus* spp. (1).
Jones Branch	1997	Meadow vole (13), meadow jumping mouse (9), *Peromyscus* spp. (1).
	1998	**Not Sampled**