THE CONSERVATION VALUE OF HEDGEROWS TO SMALL MAMMALS ON PRINCE EDWARD ISLAND

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Abstract

Hedgerows are an important landscape feature on Prince Edward Island, Canada and are often the only forested links between isolated forest fragments. Although recent studies have examined the effects of fragmentation on small mammals on Prince Edward Island (e.g, Silva et al. 2000, Silva 2001), none have addressed the use of hedgerows by small mammals. A total of 13 hedgerows and 12 forest fragments in three sites located in central Prince Edward Island were studied from May to September 2001. Hedgerows varied in length, between 70 m and 720 m, and width between 9.4 m and 31 m. Fragment area varied from 0.006 km^2 to 0.560 km^2. Large Sherman live traps were placed in the center of hedgerow vegetation at 10 m intervals throughout the length of the hedgerow, while a grid configuration was used in forest fragments with the maximum area sampled being 6400 m^2. Within each study site, hedgerows and forest fragments were sampled simultaneously. A total of 751 small mammals from 11 species were captured in 8502 trap nights. The eastern chipmunk (*Tamias striatus*) was the most abundant and widespread species, constituting 68% of the total captures. Several structural and microhabitat characteristics were measured for hedgerows and forest fragments. Hedgerow length was the most important structural variable explaining 85.5% of the variation in total captures. Species richness was positively associated with the level of hedgerow connectivity, but negatively associated with hedgerow shape (r^2=0.561, p=0.001, n=13). Variation in species richness in hedgerows was positively associated with litter depth, percent of logs, and the ratio hedgerow area-field area ($r^2=0.94$, $p=0.001$, $n=13$). Hedgerow use by the eastern chipmunk was also investigated. Chipmunks of all age and residency classes were captured in hedgerows and forest fragments. The number of resident chipmunks was positively associated with hedgerow length and hedgerow connectivity. There was no significant difference ($p>0.05$) in the distance eastern chipmunks moved in hedgerows and in forest fragments. Overall, our findings suggest that hedgerows are used by small mammals, especially eastern chipmunks, because they provide additional habitat for many woodland species occurring in an agricultural landscape. Hedgerows may help maintain viable populations of small mammals in Prince Edward Island's agricultural landscape by providing extended habitat.

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1. INTRODUCTION

1.1 Overview

Throughout the world, intense pressures on natural areas from urbanization, industry, agriculture, and forestry are resulting in habitats being confined to economically marginal land in smaller parcels (Stewart and Hutchings 1996). Habitat fragmentation is currently one of the most serious threats to biological diversity (Noss 1987). Habitat fragmentation has become a central concern in the field of conservation biology because it is taking place in natural habitats throughout the world (Harrison and Bruna 1999). The most important and extensive cause of habitat fragmentation is the expansion and intensification of human land use (Andren 1994). Habitat fragmentation is an anthropogenic process that increases heterogeneity across space by degrading once-continuous natural habitats into remnant pieces (Diffendorfer *et al.* 1995). Fragmentation involves a reduction of suitable habitat area often resulting in small, isolated fragments, patches, or remnant patches within a sea of developed land (Noss 1987).

Fragmentation, natural or anthropogenic, is common in all landscapes resulting in a mosaic of habitat patches. A mosaic is a differential distribution of resources that produces a gradient of availability and causes flows of resources or of the organisms using them (Merriam 1995). Natural fragmentation results from natural disturbances, such as wildfire, windthrow, and flooding (Smith 1992). In naturally fragmented habitats, the mosaic allows the coexistence of various species within a landscape. However, anthropogenic fragmentation partitions the landscape with artificial barriers, such as agricultural fields. A remnant patch or fragment is a result of widespread disturbance surrounding a small area (Forman and Godron 1981). The remnant of the previous community is embedded in a matrix that is disturbed. This may restrict native species to smaller habitat remnants and impede their movement between these areas (Tischendorf and Wissel 1997). Previous research has shown that increased fragmentation negatively affected the home-range size and movement of grey-tailed voles (*Microtus canicaudus*) (Ims *et al.* 1993, Wolff *et al.* 1997). In the initial stages of fragmentation, decline in the population size of a species in its original habitat is linearly related to the proportion of original habitat lost (Andren 1994). If disturbance to the matrix is chronic, a net loss of species may take place (Forman and Godron 1981). Initially net species loss may be rapid. However, over time species loss would eventually drop to zero. At a given threshold of habitat loss, isolation and area of the original habitat patch also negatively influence populations by increasing the amount of unsuitable habitat within a patch and reducing movement between remaining habitat patches. After that threshold, specifically in landscapes that are highly fragmented, patch size and isolation strengthen the decline initiated by habitat loss (Andren 1994). The latter is often the case in agricultural landscapes where forest fragments become isolated in a matrix of farm fields. Species lost in these situations either require larger habitats than the remaining fragments provide or are sensitive to the modified micro-environment within a fragment (Forman and Godron 1981).

Fragmentation has been studied in a variety of ecosystems worldwide and also at a variety of scales from the local to the landscape scale (da Fonseca and Robinson 1990, Robinson *et al.* 1992, Yahner 1992, Dunstan 1996, Henein *et al.* 1998, Laurance and Laurance 1999, Lindenmayer *et al.* 1999, Lynam and Billick 1999, Nupp and Swihart 2000). Scale refers to the spatial or temporal dimension of an object or process (Turner *et al.* 2001). Spatial fragmentation occurs at a variety of scales resulting in varying degrees of fragmented mosaics, from nearly continuous to areas with only isolated fragments of the original mosaic remaining in a matrix of introduced alien habitats (Lord and Norton 1990, Merriam 1995). A landscape describes the mosaic of habitat patches or fragments in which a particular patch or fragment is embedded (Dunning *et al.* 1992). Landscapes generally occupy a spatial scale intermediate between an organism's normal home-range and its regional distribution.

The scale of habitat fragmentation is important when assessing its possible effects on the organisms involved. For a given scale of fragmentation, generalist species tend to be less affected by fine scales of fragmentation than specialists because generalists are more able to use the surrounding matrix habitat (Lord and Norton 1990). At the individual level, fragmentation is related to area requirements (positively associated with body size), home-range boundaries, and movement patterns. At the population level, isolation of local populations, exchange of individuals between generations, and survival probabilities of local populations become important to ensure overall population persistence (Andren 1994). Ecological change that occurs within habitat fragments is often due to the invasion of the fragments by organisms found in the matrix (*e.g.*, nest predation of forest birds) (Harrison and Bruna 1999). However, some studies have found that fragmentation does not always lead to detrimental effects on all species involved (Yahner 1992, Dunstan and Fox 1996, Nupp and Swihart 1996, Bayne and Hobson 1998, Bayne and Hobson 2000).

Three major consequences of habitat fragmentation are the reduction of the total native habitat area, decline in the mean area of remaining patches, and an increase in the mean distribution of matrix or less suitable habitat between patches resulting in increased isolation of native habitat (Andren 1994, Stewart and Hutchings 1996, Harrison and Bruna 1999). When compared to continuous forests, several features of the abiotic and biotic environment in fragmented forests may be altered (Mahan and Yahner 1999). These factors include increased solar radiation, increased understory vegetation, differences in availability of food resources, and differences in predator interactions (Murcia 1995, Mahan and Yahner 1999). While the impact of habitat loss and isolation may be organism specific, the physical impacts of fragmentation are more dependent on the nature of the fragmentation itself (Lord and Norton 1990). For example, when habitat patches are part of a landscape, the presence of a species in a particular patch may be a function of the neighboring habitat (Andren 1994). Also, fragmentation may lead to chains of indirect effects and altered ecological interactions (Harrison and Bruna 1999). The loss of important predators or seed dispersers may result in changes in abundance at lower trophic levels (Harrison and Bruna 1999). As fragmentation increases, it becomes important to understand the response of organisms to various fragmentation characteristics such as patch size, isolation, and edge effects. Ultimately, this information will improve the understanding of anthropogenic activities on forest ecosystems (Bayne and Hobson 1998).

1.2 Effects of Habitat Fragmentation

Edge Effects

A prevailing feature of habitat fragmentation is a sharp increase in the amount of edge habitat when compared to unfragmented landscapes (Laurance and Yensen 1991). An edge, or ecotone, is the area where two adjacent ecosystems converge. Edge effects result from the interaction of two adjacent ecosystems when the two ecosystems are separated by an abrupt transition (Murcia 1995). Until recently, increased fragmentation and the creation of sharp edges was thought to enhance wildlife habitat values (Harris and Scheck 1991). However, it is now known that these situations may cause serious losses of residual biological value in these areas. Edge can have both a positive and negative effect on wildlife. Developing an understanding of these effects is gaining importance with the growing concern over the consequences of habitat fragmentation on natural diversity (Heske 1995).

Generally, edges are divided into two categories, inherent and induced edge. Inherent edge is a long-term feature of the landscape that results from local differences in soil type, topography, geomorphology, or microclimate. However, an induced edge is usually a short-lived, manmade feature at the junction of distinct land uses or successional stages (Yahner 1988). Inherent edges are often gradual transitions from one ecosystem to another while induced edges are often characterized by abrupt differences in vegetative structure and composition between two contiguous landscape elements (Yahner 1988). For example, in agricultural landscapes, induced edges are characterized by a narrow zone (5 m) of dense growth consisting of shrubs and saplings (Heske 1995). Deforestation creates similar edges and exposes the forest habitat to conditions found in the surrounding matrix habitat (Stevens and Husband 1998). As the amount of edge increases, the interior species usually decline while the edge species increase (Smith 1992). Gascon *et al.* (1999) found that vertebrates (*e.g.*, small mammals, birds, and frogs) that use or exploit the matrix increase or remain stable, while those that avoid the matrix habitat decline. Organisms tolerant of edge habitat and disrupted environments increase in abundance and reduce the habitat area available to forest interior species by increasing competition, predation, and parasitism of native species (Harris and Scheck 1991).

There are three different types of edge effects. First, abiotic features or environmental conditions (*e.g.*, sunlight, solar radiation, temperature) can change as a result of their proximity to the dissimilar matrix. Secondly, edge may result in changes in the abundance and distribution of species caused by the physical conditions (*e.g.*, vegetation structure and composition) near the edge. Lastly, indirect biological effects may also occur. These indirect effects may include a change in species interactions such as predation, brood parasitism, and competition (Murcia 1995). Linzey (1989) found that for white-footed mice (*Peromyscus leucopus*), the edge between disturbed and undisturbed habitats functioned as a non-structural barrier and lead to the formation of two distinct subpopulations. Similarly, Wolff and Batzli (2001) found that white-footed mice exhibited a greater prevalence of bot-fly parasitism as well as lower abundances at forest edges than interior. However, it has also been shown that some species and populations benefit from edge habitat.

Nupp and Swihart (2000) found that eastern chipmunks (*Tamias striatus*) responded positively to an increase in edge habitat. Bayne and Hobson (1998) also showed that deer mice (*Peromyscus maniculatus*) were more abundant at woodlot edges than interiors. Pasitschniak-Arts and Messier (1998) found that in prairie landscapes increased species richness was detected at edges rather than habitat interiors. It is also important to realize that edge habitat can have varying effects depending on the habitat type studied, season, size and shape of habitat patches, abundance of predators, the species studied, and home-range size and habitat use of species (Pasitschniak-Arts and Messier 1998).

Edge habitat, especially induced edge, can act as a barrier to some species while providing habitat for others. The combination of cover and access to food resources in forest-farm edges appears highly favorable for some species whose habitat requirements do not restrict their use of this area (Heske 1995). However, induced edge contrast can act as a barrier to distribution and dispersal patterns of both birds and mammals (Yahner 1988). For example, eastern chipmunks in woodlands seldom traverse fields; conversely meadow jumping mice (*Zapus hudsonius*) inhabiting fields rarely use nearby woods (Wegner and Merriam 1979). The effectiveness of edge as a barrier in a fragmented habitat might be a function of the width of the transition zone between the two habitats (Linzey 1989). Edge width at adjoining habitat patches can vary because of the nature of the vegetation in adjoining landscape elements. The vegetation structure and composition between the two elements can gradually blend together rather than change abruptly, making measurement of edge habitat subjective (Yahner 1988). Due to this, edge width may best be defined by the functional uses of edges by wildlife (Yahner 1988). As a result of increased edge, plant and animal communities in fragmented habitats generally decline, are subdivided, and exposed to ecological changes associated with edges (*e.g.*, predation, weed invasion, windthrow, and climatic exposure) (Laurance and Yensen 1991).

Area Effects

The impact of edge habitat on interior species is directly related to the size and shape of the habitat patch. A habitat patch is any discrete area that is used by a species for breeding or obtaining other resources (Fahrig and Merriam 1994). Generally, large patches of original habitat are considered more favorable than small patches. At large scales of fragmentation (*e.g.*, landscape scale), large fragments are more likely to retain more of the original species and some intact interior habitat ensuring that ecological interactions such as pollination and predation, as well as ecosystem processes like nutrient cycling remain functional (Lord and Norton 1990). As with studies on edge effects, research on area effects has yielded conflicting results. For example, Diffendorfer *et al.* (1995) showed that deer mice had a lower frequency of interpatch movement as fragment size increased from small to large patches.

Additionally, a greater proportion of animals switched from smaller patches to larger patches. Rosenblatt and Heske (1999) found that grey squirrels (*Sciurus carolinensis*), eastern chipmunks, and southern flying squirrels (*Glaucomys volans*) were only encountered in larger, more continuous sites. However, Bayne and Hobson (1998) found that American red squirrels (*Tamiasciurus hudsonicus*) and northern flying squirrels (*Glaucomys sabrinus*) were more abundant in farm woodlots than continuous forest.

Other variables affected by patch size and shape, such as predation rate, also influence animal communities within habitat patches. Previous studies suggest that predation rate increases as the ratio of edge to interior habitat increases (Wilcove *et al.* 1986, Andren and Angelstam 1988, Gardner 1998). Mahan and Yahner (1999) studied the behavior of eastern chipmunks in fragmented and continuous forest. They found that eastern chipmunks of fragmented forests spend more time in pause behaviour than those in continuous forest. Pause behaviour is associated with predator detection suggesting that chipmunks exhibited a greater predation risk in fragmented forests than continuous forests. Furthermore, Nupp and Swihart (2000) found that eastern chipmunk populations in woodlots had lower survival rates than those in continuous forest. As edge increases, generalist predators penetrate forest fragments resulting in decreased reproductive success of forest species in small fragments versus large fragments, and in fragmented landscapes versus continuous landscapes (Andren and Angelstam 1988). Fragment area can also influence the availability of food resources. Mahan and Yahner (1999) found that eastern chipmunks spent more time foraging in continuous forests than fragmented forests suggesting that more food was available in continuous forests. Villafuerte *et al.* (1997) also showed that New England cottontails (*Sylvilagus transitionalis*) residing in small patches depleted high and moderate quality forage by early winter forcing them to consume poor quality forage and forage in areas exposed to predators. These behaviors resulted in an increased mortality rate for cottontails in small patches. However, Nupp and Swihart (1996) found that white-footed mice tend to be larger in smaller forest fragments suggesting that the availability of resources is greater in smaller patches than larger patches or that competition between species is reduced in smaller patches due to a lower number of species present. Area may have a variety of effects, both positive and negative, on small mammals. Therefore, better understanding of area effects is needed in order to fully assess the overall effects of habitat fragmentation on small mammals.

Isolation and Metapopulation Theory

One of the most important effects of habitat fragmentation is isolation of populations. Two main factors leading to isolation are linear constructions, such as roads and power lines, as well as intensive agricultural land use (Mader 1984). The degree of fragment isolation is directly impacted by the nature of the matrix in which habitat fragments are embedded. A steep ecological gradient at the boundary of the fragment and matrix forms a greater barrier to movement between fragments when compared to a shallow ecological gradient (*e.g.*, boundary between two forest types) (Lord and Norton 1990). Spatial configuration of the landscape (i.e., specific arrangement of spatial elements) directly influences isolation. Characteristics of landscape structure such as size, shape, and quality of patches, presence of dispersal routes, quality of dispersal routes, and spatial configuration of the components of the landscape, are important considerations when determining the effects of isolation on species and populations (Fahrig and Merriam 1994). Rosenberg *et al.* (1997) found that small populations of organisms isolated by fragmentation exhibit higher extinction rates. The effects of isolation can be mitigated or enhanced depending on the general biology of the species involved. Fahrig and Paloheimo (1988) point out that it is important to have a good understanding of the dispersal behavior of an organism before determining whether spatial configuration of habitat patches is likely to have an important impact on population density. If an organism disperses over large distances in random directions and does not detect patches from a distance, then the spatial configuration of habitat will have less effect on population dynamics (Fahrig and Paloheimo 1988). However, for organisms that disperse along dispersal corridors, spatial relationships among habitat patches are important. The reduced ability of some woodland species such as American red squirrels and flying squirrels to disperse over large distances across an agricultural matrix may result in increased abundances of these species within forest fragments (Bayne and Hobson 1998, Bayne and Hobson 2000, Nupp and Swihart 2000). This increase in abundance may be viewed as a positive effect of fragmentation, when it actually may be detrimental to the survival of local populations of these species.

Habitat isolation and the resulting inability of some species to disperse across a hostile matrix can influence extinction probabilities of populations and possibly the metapopulation structure of these species. Hanski (1991) describes a metapopulation as a group of local populations functionally linked and sustained by dispersing individuals. As fragmentation and the distance between the remaining habitat patches increases and the size of local populations decrease, immigration between local populations becomes difficult or impossible (Smith 1992). If the landscape structure restricts dispersal, extinctions will cover larger areas and recolonization of these areas will take longer (Fahrig and Merriam 1994). The persistence of a metapopulation increases with the number and size of local populations, which is determined by the number of occupied habitat patches, as well as the rate of dispersal between them (Stewart and Hutchings 1996). The rate of local extinction relative to the rate of local recolonization determines the proportion of empty habitat patches and turnover of local populations (van Apeldoorn *et al.* 1992).

These factors imply that the metapopulation may become extinct either when fragments become too few or too small, or if dispersal between the fragments is interrupted (Stewart and Hutchings 1996). Van Apeldoorn *et al.* (1992) suggested that local extinction is largely determined by area and patch quality. However, recolonization is regulated by landscape characters (i.e., patch distance and permeability of the matrix), is expressed by the density of dispersal corridors and barriers, and is related to the dispersal ability of a species. Provided that the rate of change in dispersal behavior is greater than the rate of change in landscape spatial structure, organisms can survive in the changing landscape by moving around in it and integrating resources over space (Fahrig and Merriam 1994).

Connectivity

The ability of organisms to move through the landscape is one of the most essential aspects of metapopulation persistence or survival. Connectivity is the probability of movement of a species or a behavioral or demographic subgroup among landscape elements of a mosaic (Merriam 1995). There are two basic types of connectivity, intrinsic and extrinsic connectivity. Intrinsic connectivity results from the natural juxtaposition of similar habitats which allows dispersal, whereas extrinsic connectivity refers to artificially created or maintained dispersal corridors (Tiebout and Anderson 1997). The degree of a species' specialization and tolerance to human land use determines the importance of connectivity (Bennett 1998). Fahrig and Merriam (1985) found that white-footed mouse populations in isolated woodlots had lower growth rates than mice in connected woodlots. Furthermore, the frequency and persistence of local extinctions of white-footed mice depended on the degree to which individual patches were isolated from one another.

Landscape movements and connectivity are a function of the interactions between an organism's behavior, landscape composition (i.e., number of habitat fragments, amount of matrix habitat), and configuration (i.e., arrangement of habitat fragments) (Merriam 1995). However, different groups of animals perceive connectivity in different ways. Organisms are restricted by different levels of mobility and operate in the environment at different spatial scales (*e.g.*, within habitat fragment, local, landscape, or regional) (Bennett 1998). This means that there must be suitable linkages between resources at a scale relevant to each species (Bennett 1998). Landscape connectivity can be achieved in two ways: managing the entire landscape mosaic or managing specific habitats within the landscape to promote movement and population continuity. The first approach is suitable for species such as habitat generalists, that perceive the landscape as habitats of varying suitability with no habitat being hostile. The second approach applies to species that see the landscape as consisting of suitable habitat patches within a matrix of generally unsuitable habitat (Bennett 1998). The second approach is more applicable to many woodland small mammal species within an agricultural setting because these species are often unable to make use of the surrounding agricultural matrix and are restricted to forested areas. Habitat corridors have been proposed as a method of preserving landscape connectivity for species who perceive the matrix as a hostile environment.

1.3 Corridors

Increasing habitat fragmentation and recognizing the importance of dispersal and movement between fragments has led to the consideration of corridors as a management tool (Stewart and Hutchings 1996). The advocacy of corridors is most common in situations where only isolated fragments of habitat remain. In these circumstances, corridors can be expected to increase landscape movement (Merriam 1995). However, even though numerous studies have examined corridors, their importance to isolated populations of organisms is still unknown. A corridor is a linear habitat, embedded in a dissimilar matrix, that connects two or more larger blocks of habitat and is proposed for conservation on the grounds that it will enhance or maintain the viability of specific wildlife populations in habitat blocks (Beier and Noss 1998). Corridors may enhance the viability of populations by leading species across an inhospitable landscape toward isolated habitat remnants and have the potential to facilitate the movement of individuals from various sources (Tischendorf and Wissel 1997). Corridor structures may be temporary or permanent, stationary or mobile, but all limit the possible paths a mover may take relative to those paths possible in patches (Puth and Wilson 2001). It is important to recognize that corridors can only be considered important to conservation when animals use them to travel between isolated habitat fragments (Beier and Noss 1998). Furthermore, the success of corridors depends on their ability to increase population sizes, gene flow, and biodiversity in fragmented landscapes (Haddad 1999). The critical question concerning corridors is whether a system of protected areas connected by corridors better conserves biological diversity than other alternatives such as dispersed protected areas without connections (Harris and Scheck 1991).

Corridor Function

One of the key issues to understanding corridor function and metapopulation dynamics is identifying what constitutes quality in a corridor for a particular species or assemblage (Bennett *et al.* 1994). Forman (1991) describes five basic functions of corridors: conduit, barrier, source, sink, and/or habitat.

Conduit

As a conduit, corridors promote the movement of objects. For species that are habitat specific, metapopulation persistence may depend on the existence of corridors with suitable vegetation linking otherwise isolated habitat patches in which these animal subpopulations live (Brooker *et al.* 1999). Bennett (1990) found that in an Australian landscape, corridors facilitated continuity of isolated mammalian populations in two ways. First, individuals traversed corridors in a single movement or a series of movements punctuated by one or more periods of temporary residency. Secondly, the presence of resident animals within corridors combined with movements to and from the resident group, provided an opportunity for gene flow.

Recolonization of habitat patches depends on the exchange of individuals between habitat remnants and is accomplished by movements across heterogeneous, hospitable landscapes (Tischendorf and Wissel 1997). For species survival, the rate of change of movement in the landscape must track the rate of change in landscape structure (Henein *et al.* 1998). For less mobile species, increased fragmentation leads to increased isolation and decreased population persistence, while for more mobile specialists, movement among patches enables them to knit together enough traditional resources to persist (Henein *et al.* 1998). The effect of corridors on the rate of immigration can be explained at the individual level by how organisms orient their movements in the presence of a corridor (Rosenberg *et al.* 1997). The effectiveness of corridors in facilitating movement may be due to the increased probability of successful movements within the home range of an individual, and/or increased movements of individuals among subpopulations through dispersal of young produced in the corridor (Rosenberg *et al.* 1997).

Source

Corridors may also act as sources for some populations. Source habitats are areas of high productivity and are important in maintaining less productive sink habitats through continued emigration into these areas (Pulliam 1988). By serving as sources and permitting movement, corridors should increase the immigration rate among isolated habitat leading to higher abundances and species richness in connected patches (Perault and Lomolino 2000).

Sink

However, corridors may also act as sinks by promoting the expansion of invading species (i.e., non-native plants), disease, and generalist predators (Forman 1991). Sink habitats, areas where within-habitat reproduction is insufficient to balance local mortality, may support very large populations even though populations in these habitats would eventually become extinct without continued immigration (Pulliam 1988). Hess (1994) developed a model and demonstrated that in specific cases, extinction rates in connected landscapes increased dramatically surpassing the extinction rate in a landscape of isolated patches. In these cases, disease induced mortality was low enough to allow infected individuals to spread disease and high enough to reduce population levels to a level that random demographic and environmental effects cause extinction (Hess 1994). Corridors can also serve as sinks by altering the structure of some populations. Downes *et al.* (1997) found that for native bush rats (*Rattus fuscipes*), males were more abundant in corridors than females when compared to forest habitat. Also, females found in the corridors weighed less than those in forest habitat. Both of these findings suggest that corridors may affect the social structure and reproduction of bush rats living in or moving through corridors. Finally, corridors may also provide habitat for some species. In narrow corridors, only generalist or edge species are expected to be present where as wide corridors may also contain interior species (Forman 1991).

External and Internal Features of Corridors

The high degree of variation in the results of corridor studies has lead to a lack of consensus as to what makes a corridor beneficial to organisms (Perault and Lomolino 2000). Newmark (1993) points out that given the rapid loss of habitat and species worldwide, the design of wildlife corridors must give special consideration to the habitat requirements of target species. Corridor use is believed to depend on the degree to which the area contrasts with the patch habitat and not necessarily the composition of the corridor habitat (Rosenberg *et al.* 1997). External and internal features of corridors may affect their function in the landscape. External features include length, connectivity, and the presence of gaps. These structural attributes describe the form of the corridor as well as its relationship with adjacent patches and surrounding environmental conditions (Forman 1991). Internal characteristics emphasize the two-dimensional view and include variables such as width, adjoining land use types, and vegetation species composition. These characteristics determine the function of the corridor (Forman 1991). Many studies have focused on the geometrical aspects of corridors and less emphasis is given to assessing the habitat conditions of corridors (Perault and Lomolino 2000). The three major components of corridors that have been quantified include habitat characteristics, width, and linear continuity. Habitat determines the availability and abundance of essential resources. Width is the area available to animals and influences the intensity of "edge effects", such as microclimatic changes, weed invasion, and predation. Finally, linear continuity is the proportion of gaps along the length of a corridor (Bennett *et al.* 1994). Each of these variables may influence corridor use by different species. For example, width may influence corridor use by oldfield mice (*Peromyscus polionotus)* (Danielson and Hubbard 2000). Corridors did not have a strong effect on the movements of this species. However, the 32 m corridor width may have resulted in the corridors being viewed as additional habitat rather than dispersal corridors. Ruefenacht and Knight (1995) found that corridor gaps and width did not affect movements or crossings of non-resident deer mice. Corridor gaps were defined as areas 10 m wide areas (gap length was dependent on corridor width) where all vegetation ≤ 7 cm diameter breast height was removed. However, tree density in the corridors and gaps were important to deer mice. Increased tree density resulted in the highest number of gap crossings as well as an increased amount of movement regardless of continuity or width (Ruefenacht and Knight

1995). Bennett *et al.* (1994) found that the abundance of resident chipmunks in corridors was best predicted by features of the habitat while the abundance of transients was best predicted by a combination of linear continuity and habitat. Furthermore, Downes *et al.* (1997) found that in Australia, a higher number of native mammal species were found in corridors close to forest patches than corridors distant from patches. Also, arboreal mammals were more abundant in corridors than terrestrial mammals demonstrating that different species prefer corridors of different habitat types.

Habitat Corridors

While wildlife are unable to recognize corridors for their functional role in movement, they will recognize appropriate habitat (Newmark 1993). Habitat corridors are likely to promote landscape connectivity in four different situations: 1) where a large part of the landscape is modified and inhospitable to native species; 2) for species that are habitat specialists as well as species that have a limited scale of movement relative to the distance that must be traversed; 3) where the goal is to maintain population continuity between habitats and/or continuity of entire faunal communities; 4) where the maintenance of ecosystem processes requires continuous habitat for their function (Bennett 1998).

There are two distinct types of habitat corridors based on function: those that facilitate movement but are not acceptable living habitat, and those that serve as living habitat, as well as being used for movement across the landscape (Bennett *et al.* 1994). A study on root voles (*Microtus oeconomus*) demonstrated that corridors may function as movement corridors and living habitat thereby increasing the effective area available to individuals during normal within-home-range movements (Andreassen *et al.* 1998). Henderson *et al.* (1985) found that among local populations of eastern chipmunks, individuals use corridors as habitat as well as movement pathways. Within the general category of habitat corridors there are five sub-groups based on corridor origin and degree of disturbance. Distinguishing between different types of corridors is useful because it indicates the likely composition and quality of habitat for wildlife (Bennett 1998). The five sub-groups include natural habitat corridors, remnant corridors, regenerated corridors, planted corridors, and disturbance corridors. Natural habitat corridors are the result of natural environmental processes (*e.g.*, streams); remnant habitat corridors are strips of forest vegetation that remain after the surrounding environment has been altered; regenerated habitat corridors occur as the result of regrowth of a strip of vegetation that was formerly cleared or disturbed; planted corridors have been established by humans and are frequently composed of non-native plant species (*e.g.*, plantations, windbreaks); and finally, disturbance corridors are linear, disturbed areas that differ from the surrounding environment (*e.g.*, railway lines, roads) (Bennett 1998).

1.4 Hedgerows as Corridors

Agricultural landscapes isolate populations of woodland species in habitat patches (Henderson *et al.* 1985) by destroying natural habitat patches and introducing matrix habitat (i.e., crops) into the landscape. Hedgerows or small strips of vegetation, form extensive networks in agricultural landscapes (Tischendorf and Wissel 1997). Hedgerows may be planted or spontaneous, but always have a human component and are managed to prevent expansion into adjacent fields (Baudry *et al.* 2000). Windbreaks, or hedgerows, are used by farmers to reduce wind erosion and to reduce physical damage to crops by wind (Finch 1988). While the primary role of hedgerows is to provide protection to crops, exposed soil in winter, and livestock, they can also be used for beautification of property, decrease snow drifting across roadways, and provide noise reduction near roads (Himelman and Arsenault 1983). Although the primary functions of hedgerows do not focus on their usefulness to wildlife, hedgerows may provide benefits to wildlife living in agricultural landscapes. Linear patches such as hedgerows, can serve two functions in fragmented landscapes. First, they can be used as movement pathways and secondly, as habitat for residents (Rosenberg *et al.* 1997). Hedgerows with distinct boundaries can serve as extended habitats by providing for an organism's daily requirements, such as foraging and shelter (Tischendorf and Wissel 1997). Linear patches may be used for movement as well as habitat, but in order to determine the value of linear patches to conservation it is important to determine which function is primary (Rosenberg *et al.* 1997).

Several studies have shown that hedgerows are important landscape structures for a variety of species. In England, hedgerows have been found to be important for many bird species (Fuller *et al.* 2001). While hedgerows did not provide habitat for some specialist species, they were important for several species that were scarce in woodland habitats. Hedgerows are also beneficial to many woodland small mammal species living within an agricultural landscape. Henderson *et al.* (1985) found that hedgerows serve as movement corridors and habitat for small breeding populations of eastern chipmunks. They concluded that wooded hedgerows are important for eastern chipmunks and provided sufficient habitat connectivity to permit population continuity throughout the farmland mosaic. Henein *et al.* (1998) also found that fencerows were important to eastern chipmunks. The loss of these features or a reduction in their quality had detrimental effects on persistence, population size, and variability. Previous studies in Australian agricultural landscapes have determined that linear habitats are important for the majority of native mammals present in the system and should be retained (Downes *et al.* 1997, Laurance and Laurance 1999). Furthermore, using radio-telemetry, Wauters *et al.* (1994) showed that tree rows and hedgerows were used by juvenile Eurasian red squirrels (*Sciurus vulgaris*) for dispersal and by adults (predominantly males) for movement and foraging. Similarly, Haddad (1999) showed that corridors direct interpatch movement and have a positive influence on population sizes of habitat restricted butterflies. Hedgerows may not only be important to animal species but also to the vegetative communities. Harris (1984) points out that fencerows and other "environmental corridors" increase dispersal of climax tree species and affect tree species distribution by influencing the travel of seed dispersing wildlife. However, McCollin *et al.* (2000) found that the environments of woodlands and hedgerows differ in quality for plants. The plant composition of hedgerows was consistent with conditions similar to an environment that is significantly drier and more continental with a higher soil nitrogen status and lower soil acidity. When considering all of these factors, they concluded that hedgerows were not good corridors for the dispersal of woodland plants.

In order to understand corridor function and the dynamics of metapopulations, characteristics that constitute quality in a corridor for a particular species assemblage must be identified (Bennett *et al.* 1994). While hedgerows have been shown to be beneficial to many species, it is unclear what features of hedgerows are most important to ensure survival of fragmented populations. Fitzgibbon (1997) suggested that the amount of connectedness of habitat fragments and the length of adjoining hedgerows was the most important factor for determining abundances of wood mice (*Apodemus sylvaticus*) in autumn. Conversely, abundances of bank voles (*Clethrionomys* *glareolus*) in autumn were more influenced by the number of hedgerows rather than hedgerow length (Fitzgibbon 1997). The abundance of resident eastern chipmunks was best predicted by habitat features of the hedgerow while that of transient individuals was best predicted by both linear continuity and habitat of the hedgerow (Bennett *et al.* 1994). Henderson *et al.* (1985) found that the lack of woody cover did not prevent movement of eastern chipmunks through fencerows suggesting that even poorly vegetated fencerows have vegetation characteristics that are distinguishable from agricultural fields. Yahner (1982, 1983) showed that the abundance of white-footed mice and southern red-backed voles (*Clethrionomys gapperi*) was positively associated with the dispersion of fallen logs, tree stumps, and man-made objects in the hedgerow. Also, white-footed mice were positively associated with the number of woody species, the presence of tall forbs, large trees, and dense woody undergrowth and shrubs (Yahner 1983). Similarly, northern short-tailed shrews (*Blarina brevicauda*) and masked shrews (*Sorex cinereus*) showed a preference for shrubby habitat. Overall, the size of shelterbelts and features that created microhabitat complexity were positively associated with greater species richness. Therefore, Yahner (1983) concluded that community structure within hedgerows is enhanced if hedgerows are characterized by features that simulate or characterize those occurring in mature natural habitats. In England and Wales, Kotzageorgis and Mason (1997) found that small mammals use hedgerows permanently, sporadically, or as dispersal corridors between patches of prime habitat. Three of the five species found in hedgerows permanently used them while two other species were found only in hedgerows with good habitat structure. Intensity of agriculture in the landscape can also affect hedgerow use. Wegner and Merriam (1990) found that white-footed mice in low intensity agricultural systems used farm fields and fencerows almost equally. At intermediate intensity, where crop production was higher and fencerows were narrower with less woody vegetation, mice used fields more intensively than fencerows. These studies illustrate the variety of responses from different species and demonstrate the need for further investigation into the factors affecting hedgerow quality. A better understanding of associations between habitat variables and the use of habitats by different species are required for proper establishment and maintenance of shelterbelts by private landowners and agencies (Yahner 1983).

1.5 Land Use and Prince Edward Island

History

Prince Edward Island is located in the Gulf of St. Lawrence (46° to 47° N, 61.9° to 64.4° W) and encompasses an area of approximately 5660 km^2 (Weighs 1995). The original forests of Prince Edward Island (P.E.I.) were considered part of the Acadian Forest Region, characterized by high-quality hardwoods including sugar maple (*Acer saccharinum*), yellow birch (*Betula alleghaniensis*), and beech (*Fagus grandifolia*) (Round Table Report 1997).

Extensive agriculture and timber harvesting practices have resulted in fragments of early successional, even-aged forest characterized by low quality softwoods such as the white spruce (*Picea glauca*) (Round Table Report 1997). During the last three centuries, trees were seen as either an obstacle to settlement or as a source of revenue for settlers (Johnston 2000). Suitability of Prince Edward Island's soils for agriculture led to the major clearing of native forest. Large scale methods of deforestation began in the 1800s when timber was used for shipbuilding and export. The best red oak (*Quercus rubra*) and white pine (*Pinus strobus*) were cut for shipbuilding (Johnston 2000). In 1904, the provincial forestry commission recognized and investigated the decline of the island's forests and presented nine suggestions for future forest management (P.E.I. Dept. of Energy and Forestry 1987). These suggestions included: 1) using timber lands for their utmost cash value, excluding use for ornamental and other purposes; 2) establishing and maintaining double offset rows of spruce for windbreaks; 3) developing and popularizing Arbor Day; 4) establishing trees to delineate public road bounds; 5) ensuring regeneration by using selective, strip, or group methods of cutting; 6) thinning stands to favor better trees and promote regeneration; 7) establishing trees on school grounds for teaching purposes; 8) training teachers with elementary skills in tree planting and silviculture so they can in turn teach students; and 9) establish a forest nursery on a government farm to grow seedlings and distribute them to farmers at cost.

The rate of deforestation peaked in the early 1900s but deforestation has continued throughout the century for potato production and farming (Johnston 2000). As cleared fields regenerated into forested areas, the Acadian forest was replaced by mostly shorter-lived softwoods such as the white spruce (*Picea glauca*). A lack of diversity in today's Island forests is a result of past harvesting and land use practices (Johnston 2000). While timber harvesting is still occurring on the island, on government land, management practices are attempting to take into consideration other aspects of the forest ecosystem. In a 1987 Management Plan for the Eastern District Crown Land, forest prescriptions included the development of wildlife habitat through specific silvicultural/wildlife integration techniques (P.E.I. Dept. of Energy and Forestry 1987). The plan involved retaining cover patches, snag trees, and wildlife valued trees, encouraging a percentage of hardwood trees be left in softwood stands and vice versa, creating edge habitat, and maintaining existing hedgerows as well as planting new hedgerows where necessary (P.E.I. Dept. Energy and Forestry 1987). Also, the 1993 Prince Edward Island State of the Forests report showed that the island's forests are returning to a more diverse state than was found in the mid-1900s. In 1946, the dominant covertype covering approximately 80,000 hectares was softwood, while pure hardwood stands covered less than 10,000 acres. However, in 1990, the covertype pattern showed a 52-48 distribution between pure stands and mixed wood covertypes and a 54-46 distribution between predominantly hardwood covertypes and softwood covertypes (P.E.I. Dept. of Agriculture, Fisheries, and Forestry 1993). Furthermore, organizations such as the Macphail Woods Ecological Forestry Project in Orwell, are attempting to aid the recovery of the Acadian forest through selective harvesting and planting activities (Macphail Woods Ecological Forestry Project, http://www3.pei.sympatico.ca).

Current Land Use and Hedgerow Management

Despite improvements in P.E.I.'s forests over the past 50 years, agricultural and timber harvesting practices are still a threat to remaining forested areas. The total acreage under crops has risen from 386,715 acres in 1986 to 420,971 acres in 1996 (P.E.I. Dept. Agriculture and Forestry 2001). Potato production has continued to expand on P.E.I. from less than 70,000 acres in 1988 to 113,000 acres in 1999 (P.E.I. Dept. Agriculture and Forestry 2001). The demand for construction grade lumber and pulpwood has also increased, encouraging record harvesting activity. Land on Prince Edward Island is 88% privately owned and its use is essentially unregulated (Round Table Report 1997). Few studies have been conducted to determine the effects of these land use practices on the Island's wildlife. Although recent studies have investigated the effects of fragmentation on the abundance and species richness of small mammals in forest fragments on Prince Edward Island (Silva 1999, Silva *et al.* 2000, Silva 2001), they do not focus on the significance of hedgerows in the agricultural landscape. Hedgerows are an important landscape feature on

Prince Edward Island. In eastern North America and Canada, fencerows are often under threat from mechanized farming and are removed in order to facilitate field expansion (Baudry *et al.* 2000). Few areas of continuous forest still exist on the island and in many cases, hedgerows are the only links between forest patches. Therefore, it is fundamental to determine the importance of hedgerows to wildlife.

On Prince Edward Island, it is thought that most local hedgerows were not planted but established themselves along fencelines (Pharoah 1983). Historically, most hedgerows consisted of a single or double row of trees and management included flailing or cutting of the understory to control weeds (Stewart 1999). In the 1970's and 1980's, maintenance of hedgerows by landowners declined and government incentives to remove hedgerows began resulting in a loss of hedgerows (Stewart 1999). This was also coupled with an increase in field size and use of large machinery, resulting in hedgerows being viewed as impediments to farmer's work (Stewart 1999). Currently, landowners are again recognizing the benefits of hedgerows. In 1997, the Round Table on Resource Land Use and Stewardship recommended that hedgerows be used as part of the island's soil conservation project. They also suggested that individual farmers be provided with financial incentives to improve existing hedgerows and to establish new hedgerows. Furthermore, to the non-farmer, hedgerows are important visual elements determining aesthetic appreciation of the countryside (Round Table Report 1997).

In the design of windbreaks for crop protection and crop production benefits, the types of windbreak systems vary from minimal inputs of land, labor, and capital to those requiring much larger inputs (Finch 1988). The degree of protection a windbreak provides depends on its orientation, height, density, species composition, and spacing (Finch 1988). On Prince Edward Island, problem winds occur from the northwest, thus hedgerows should be located on the north and west of the property forming an 'L' shape (Himelman and Arsenault 1983). The ideal hedgerow for crop protection contains three rows of trees separated by at least two meters. Hedgerows should also be separated from fields by a thin margin of grass (Stewart 1999). Evergreen trees are recommended as the primary species in hedgerows, with white spruce being the best choice, because this species is hardy and provides almost a solid barrier to the wind throughout the year (Himelman and Arsenault 1983). However, hedgerows should also include tall deciduous trees which extend the protected area, and low shrubs to trap snow, control grasses, and provide shelter and food for wildlife (Stewart 1999). Hedgerows on Prince Edward Island share several common characteristics depending on the direction they face. Hedgerows facing the north and west contain a spruce backbone while hedgerows on the south and east sides of properties contain a mixture of hardwoods with shrubs producing the understory (Pharoah 1983).

The increasing human population and expansion of anthropogenic disturbance threatens the existence of many plants and animals. Approximately 12% of the earth's land area has been converted to cities, suburbs, and intensive agriculture but a much greater percentage has been altered through livestock grazing, harvesting timber and wildlife, disposal of toxic wastes, and a variety of other activities (Brown 1995). Habitat fragmentation is a problem that continues to threaten many species. In areas dependent on and fragmented by agriculture, such as Prince Edward Island, understanding the structure of fragmented populations becomes especially important. On Prince Edward Island, existing hedgerows have the potential to provide necessary connectivity to allow the persistence of many small mammals, which constitute a large portion of the Island's mammalian fauna. By understanding the importance of hedgerows to small mammals we can better manage agricultural areas to maximize the viability of various fragmented animal communities.

1.6 Small Mammals of Prince Edward Island

For the purpose of this study, small mammals are confined to non-flying mammals weighing less than 250 g. Previous studies have determined that there are 15 species of small mammals present on the island (Bateman and Prescott 1984, Silva *et al.* 2000, Silva 2001). However, due to the specific habitat requirements of each species, only 11 species were expected to be encountered in the framework of this study. The species in this subset include two insectivores, one carnivore, and eight rodents. Three other insectivores, the smoky shrew (*Sorex fumeus*), pygmy shrew (*Sorex hoyi*), and water shrew (*Sorex palustris*), also occur on Prince Edward Island but were not included in this subset. Previous research has shown that the smoky shrew and pygmy shrew may be rare on the island (Bateman and Prescott 1984, Hartling 2000). Also, the water shrew occurs primarily near bodies of water (Wilson and Ruff 1999). Since there was no water adjacent to or within the hedgerows and forest fragments studied, capture of the shrew was unlikely. A brief description of the life history and habitat requirements of each highlighted species is discussed below.

Masked Shrew

The masked or common shrew (*Sorex cinereus*; mass = 2.4-7.8 g; Whitaker 1996) is a widely distributed insectivore common in coniferous and northern deciduous forest biomes (Wilson and Ruff 1999). The masked shrew is found in a variety of habitats ranging from wet to dry forests, shrub thickets, and grassy and herbaceous areas. This shrew is primarily nocturnal and is noted for its particularly large appetite (Whitaker 1996). Its daily consumption of insects often equals or exceeds its own weight making it difficult to keep them alive during live capture. Often, masked shrews are found dead in the trap. Silva *et al.* (2000) found that the masked shrew is the most widespread insectivore within the Prince Edward Island National Park. While this species was captured in most habitat types within the park, abundances were low. Previous studies conducted outside the national park found that the common shrew was the most abundant and widespread species occurring in both softwood and hardwood stands (P.E.I. Dept. of Agriculture and Forestry 1983). Yahner (1983) showed that masked shrews were present in shelterbelts and exhibited a preference for shrubby habitat with a low density of forbs. While the abundance of common shrews on Prince Edward Island may vary by location, it is expected that masked shrews will be captured in both forest fragments and hedgerows, especially those characterized by shrubby habitat and a low density of forbs.

Northern Short-tailed Shrew

The northern short-tailed shrew (*Blarina brevicauda*) is the largest shrew (mass = 14-29 g; Whitaker 1996) in North America. In the northern part of its range, the short-tailed shrew inhabits a variety of habitats, particularly those areas with good canopy cover and thick ground cover (Wilson and Ruff 1999). Northern short-tailed shrews are most common in areas with more than 50% cover (George 1986). This species is semi-fossorial and excavates underground runways to patrol for prey. Northern short-tailed shrews are generally solitary and meetings between individuals of this species often result in combat (Whitaker 1996). The breeding season of this species occurs from early February to late September, with two peaks occurring in spring and late summer to early autumn (George 1986). Owls are the greatest predators of this species. Mammalian predators will often discard kills because of the musky odor produced by glands (Wilson and Ruff 1999). Abundance of short-tailed shrews has been positively associated with the presence of tall woody foliage and preference for shrubby habitats (Yahner 1983). Within the Prince Edward Island National Park, the short-tailed shrew was only found within the Acadian forest habitat type (Silva *et al.* 2000). However, the short-tailed shrew was found to be widely distributed outside the park (Hartling 2000). It is expected that short-tailed shrews will be captured in most forest fragment and hedgerow habitats outside the national park.

Short-tailed Weasel

The short-tailed weasel or ermine (*Mustela erminea*; mass = 45-182 g; Whitaker 1996) has the most widespread distribution of all mustelid species. The short-tailed weasel is found in a variety of habitats including open woodlands, brushy areas, grasslands, wetlands, and farmland. However, local distribution of this species is related to that of small rodents and lagomorphs (King 1983). This species is primarily nocturnal but can be active throughout the day (Wilson and Ruff 1999). This carnivore hunts mainly on the ground and preys upon mice, voles, shrews, young rabbits, squirrels, and a variety of amphibians, reptiles, and insects (Whitaker 1996). Populations of short-tailed weasels are influenced by fluctuations in the supply of prey, especially small mammals (King 1983). A weasel's den is usually found in or beneath a log, stump, roots, brush pile, or stone wall. Short-tailed weasels also use old chipmunk burrows for dens (Whitaker 1996). Weasels are not a primary species of interest in this study and due to their secretive nature are not expected to be captured in high abundances. However, previous research shows that they were captured more frequently in linear habitats than forest patches (Silva 2001). Therefore, it is expected that weasels will primarily be captured in hedgerows.

American Red Squirrel

The American red squirrel or pine squirrel (*Tamiasciurus hudsonicus*) is most commonly found in coniferous forests but also occupies mixed coniferous and deciduous forests (Wilson and Ruff 1999). The American red squirrel is the smallest tree squirrel in its range (Whitaker 1996) but is the largest (mass = 140-252 g; Whitaker 1996) Sciuridae to occur on Prince Edward Island. American red squirrels prefer boreal coniferous forests that provide abundant conifer seeds, fungi, and interlocking canopy for efficient foraging and escape from predators (Steele 1998). Suboptimal habitat includes hedgerows throughout its range. The primary food of this species is conifer seeds which it stores in one or more large caches. This species is active throughout the year with the exception of periods of inactivity during inclement weather (Whitaker 1996). American red squirrels typically produce only one litter per year (Steele

1998). Due to the primarily arboreal nature of this species, it is expected that capture rates may not adequately reflect its actual abundance, especially if ground traps are used. However, American red squirrels have been found to be ubiquitous in terms of habitat requirements (Bayne and Hobson 2000) and this species is expected to be captured in all hedgerow and fragment habitats that contain coniferous trees.

Eastern Chipmunk

The eastern chipmunk (*Tamias striatus*; mass = 66-139 g; Whitaker 1996) occurs in hardwood stands within the boreal forest as well as in all other deciduous forest associations. Eastern chipmunks also occur near human dwellings making them an urban species as well as wilderness species (Snyder 1982). This species is primarily a ground species and uses burrow systems for food storage, escape, and reproduction (Wilson and Ruff 1999). Burrows are up to 3 m long and less than 1 m deep (Whitaker 1996). Eastern chipmunks are territorial and defend a core area around their burrow. From late fall to early spring, eastern chipmunks are mostly underground in torpor only appearing above ground during favorable weather (Snyder 1982). Most matings occur between late February and early April and again in late June and early July. Eastern chipmunks feed on nuts, seeds, and other types of vegetation. The primary predator of this species is the short-tailed weasel. The eastern chipmunk is the most abundant small mammal species and was captured in all types of wooded habitat (Acadian forest, mixed forest, hardwood forest, red pine plantation) in the Prince Edward Island National Park (Silva *et al.* 2000, Silva 2001). In addition, hedgerows have been shown to provide important habitat for eastern chipmunks (Henderson *et al.* 1985, Bennett *et al.* 1994). Therefore, it is expected that eastern chipmunks will be encountered in both forest fragments and hedgerows during this study.

Northern Flying Squirrel

The northern flying squirrel (*Glaucomys sabrinus*; mass = 45-70 g; Whitaker 1996) is most often associated with fairly dense conifer forests but also lives in mixed conifer deciduous forests. This species is nocturnal and seldom seen. Mushrooms and fungi make up a large portion of the flying squirrel's diet but this species also eats seeds, nuts, and fruit (Wilson and Ruff 1999). While flying squirrels spend a considerable amount of time foraging on the ground, they are dependent on trees for locomotion and nesting (Wells-Gosling 1984). Within the Prince Edward Island National Park, northern flying squirrels were only captured in two habitat types: hardwood forests and red pine plantations (Silva *et al.* 2000). While this species is usually associated with old-growth and mature forests, studies have shown that it can survive, and may even thrive, in farm woodlots (Bayne and Hobson 1998, Silva *et al.* 2000). During the course of this study, it is expected that flying squirrels will be captured in forest woodlots and possibly hedgerows, but due to its arboreal nature captures may not adequately reflect abundance. The presence of this species in hedgerows is unlikely.

Southern Red-backed Vole

The southern red-backed vole (*Clethrionomys gapperi*; mass = 6-42 g; Whitaker 1996) is a semi-fossorial species. It inhabits chiefly mesic habitats in coniferous, deciduous, and mixed-wood forests with abundant stumps, logs, and exposed roots (Wilson and Ruff 1999). Red-backed voles use natural runways, such as rocks and logs, to move throughout their habitat. This species feeds on green herbaceous vegetation and a variety of berries (Whitaker 1996). During periods of snow cover, the home-range of red-backed voles is extended. The breeding season of this species lasts approximately seven months of the year and occurs from late winter to late fall. Density of this species tends to increase during the summer months with peak numbers in late summer and early fall and a gradual decline through the winter. Unlike other vole species, red-backed vole population do not experience three to four year population oscillations (Merritt 1981). The primary predators of this species are hawks and weasels (Whitaker 1996). Red-backed voles are an important component of the short-tailed weasel diet (Merritt 1981). Previous studies have found that this species is relatively common in Prince Edward Island (P.E.I. Dept. of Agriculture and Forestry 1983, Silva *et al.* 2000). Therefore, it is expected that this species will be captured in hedgerows and fragments that contain logs and other objects on the ground.

Meadow Vole

The meadow vole (*Microtus pennsylvanicus*; mass = 20-70 g; Whitaker 1996) is dependent on grassy fields and meadows. While this species is sometimes found in other areas, it is unable to survive and reproduce in other habitats (Wilson and Ruff 1999). The meadow vole is active usually at night. This species forages almost entirely on green vegetation and tubers (Whitaker 1996). The meadow vole follows a well-developed three to four year population cycle and is a mainstay in the diet of many carnivores (Whitaker 1996). This species is particularly abundant in fields on Prince Edward Island (D. Guignion, pers. comm.). However, since this is primarily a grassland or field species, it is expected that few individuals will be captured within hedgerows or forest fragments.

Meadow Jumping Mouse

The meadow jumping mouse (*Zapus hudsonius*; mass = 13-28 g; Whitaker 1996) is found in mostly grassy or weedy fields and may also occur in the woods, especially where the woodland jumping mouse does not occur (Wilson and Ruff 1999). This species feeds primarily on seeds, fruits, invertebrates, and fungi. The meadow jumping mouse hibernates from late October to late April (Whitaker 1996). Breeding occurs soon after emergence from hibernation and two to three litters are produced each year with most young produced in June and August (Whitaker 1972). Within the Prince Edward Island National Park, this species was confined to the dune and wetland habitat types (Silva *et al.* 2000). However, this species was found to be abundant in agricultural landscapes outside the national park (M. Silva, pers. comm.). Therefore, it is expected that this species is also present in hedgerows due to their close proximity to agricultural fields.

Woodland Jumping Mouse

The woodland jumping mouse (*Napaeozapus insignis*; mass = 17-26 g; Whitaker 1996) is found only in wooded habitats, especially in areas with dense, green vegetation. This species selects cool moist environments within the forest or forest edge, with its overall distribution being more restricted by the availability of suitable vegetation (Whitaker 1972). The woodland jumping mouse is the best jumper in its family and when in a hurry, will make great leaps of 2-2.4 m (Whitaker 1996). Woodland jumping mice live in burrows and feed on seeds, insects, subterranean fungi, and berries. Like the meadow jumping mouse, this species hibernates from October to April. The breeding season of this species occurs from May to September with most breeding occurring in June and August (Whitaker 1972). Within the Prince Edward Island National Park, the woodland jumping mouse was captured in three habitat types, the hardwood forest, red pine plantation, and bog (Silva *et al.* 2000). It is expected that this species will be found more often in wooded fragments of varying habitat types than in hedgerows.

Deer Mouse

The deer mouse (*Peromyscus maniculatus*; mass = 10-33 g; Whitaker 1996) is the most widespread North American rodent (Wilson and Ruff 1999). This species is found in almost every habitat and is highly variable in appearance (Whitaker 1996). The deer mouse is nocturnal and crepuscular with little activity occurring during the day. The deer mouse feeds on seeds, nuts, fruits, berries, and insects. The deer mouse is also an important prey for almost every type of predator, including weasels (Whitaker 1996). In previous studies, this species has shown no affinity for edges and is considered a generalist (Pasitschniak-Arts and Messier 1998). Silva (1999) found this species to be the second most abundant and widespread species in the Prince Edward Island National Park. However, previous studies conducted outside the national park suggest that this species is uncommon on Prince Edward Island (P.E.I. Dept. of Agriculture and Forestry 1983). Based on this information, it is expected that deer mice will be captured in both forest fragments and hedgerows.

2. GENERAL OBJECTIVES

The overall goal of this study was to determine the conservation value of hedgerows to small mammals on Prince Edward Island. The general objectives of this project are organized into three sections.

1. To determine the abundance and diversity of small mammals within hedgerows and to investigate the relationship between small mammal abundance and structural aspects of hedgerows.

2. To examine characteristics of the surrounding landscape (macrohabitat) as well as microhabitat conditions of hedgerows and determine how these factors influence the abundance of small mammals in hedgerows. This includes assessing the influences of surrounding forest fragments and land use on small mammal abundance.

3. To determine whether hedgerows are used by the eastern chipmunk as movement corridors or as extended habitat for foraging and breeding. This section focuses on distances eastern chipmunks move in hedgerows and whether hedgerows are used as permanent living/breeding habitat.

Summary of Specific Objectives

Objective 1

A. To determine the diversity and abundance of small mammal species in hedgerows and habitat fragments associated with hedgerows.

B. To determine how structural aspects of hedgerows such as length (m), width (m), and connectivity influence the abundance and diversity of small mammals.

I expect that small mammal species richness and diversity within hedgerows will will be similar to adjacent forest fragments with long, wide hedgerows containing the greatest species richness and diversity.

Objective 2

A. To determine what microhabitat characteristics of hedgerows are important for small mammals. Microhabitat characteristics included percent canopy cover, percent ground cover, percent of logs, litter depth, and soil moisture.

B. To determine the effect of various macrohabitat/landscape factors on small mammal abundance within hedgerows. Macrohabitat/landscape factors included the proportion of gaps in hedgerows, the area of the surrounding fields, and the area of the connecting forest fragments.

I expect that hedgerows with the greatest microhabitat complexity will contain the highest small mammal species richness and abundance. Also, I expect that the proportion of gaps and area of the surrounding fields will be negatively associated with small mammal species richness and abundance, while the area of the connecting forest fragment will be positively related to species richness and abundance of small mammals in hedgerows.

Objective 3

A. To determine if hedgerows are used by eastern chipmunks as movement corridors and/or as extended portions of habitat.

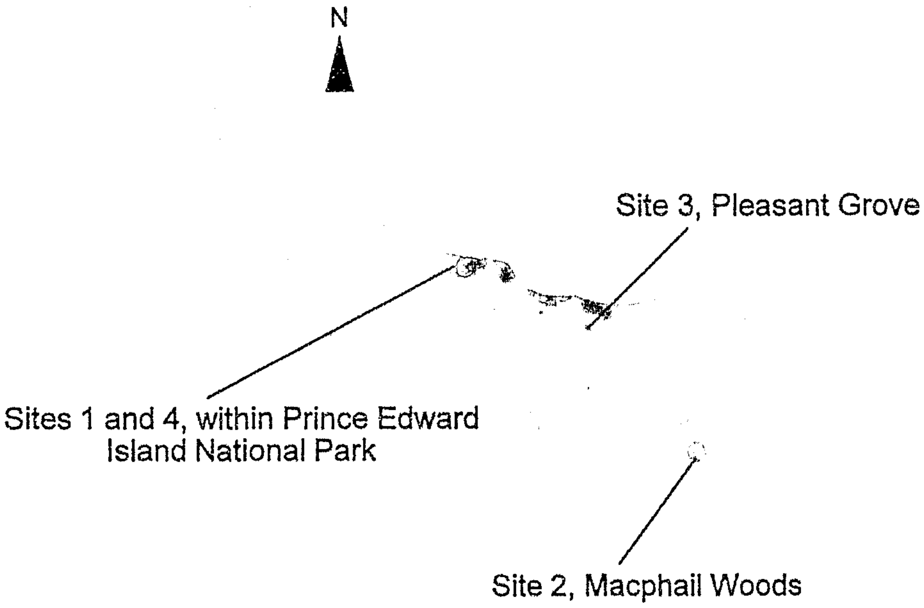
B. To determine the distances eastern chipmunks move within hedgerows and forest fragments.

I expect that eastern chipmunks use hedgerow as both movement corridors and extended habitat. Also, I expect that eastern chipmunks move longer distances in hedgerows.

3. DESCRIPTION OF STUDY AREAS

This study was conducted from May to September 2001 and included four study sites in three different forest systems located across Queens County, P.E.I. (Figure 3.1). Two sites were located within Prince Edward Island National Park (PEINP). These sites were initially chosen because they were previously used for studies on the abundance of small mammals and the effects of habitat fragmentation on small mammals in PEINP (Silva 1999, Silva *et al.* 2000, Silva 2000). The remaining two sites (Macphail Woods Ecological Forestry Project and Pleasant Grove) were located outside the national park and were selected using 1990 provincial forest inventory data (P.E.I. Department of Agriculture and Forestry 2001) coupled with a Geographic Information System (MapInfo:GIS). The criteria used to select these sites were: 1) forest fragments with a similar covertype, 2) a network of forest fragments with at least three connecting hedgerows, and 3) a range of variation in hedgerow length and width. The criteria were selected to reduce potential variability between small mammal communities found within each site, to maximize the number of hedgerows studied, and to examine the effects of hedgerow structure on hedgerow use by small mammals. Sites were also selected based on the type and intensity of agricultural use in the adjacent areas. Three sites were surrounded only by low intensity agricultural crops such as hay and barley. However, the Macphail Wood site also included two

Figure 3.1. Map of Prince Edward Island showing the location of the four study sites.



adjacent fields that were planted with soybeans as part of a potato crop rotation. According to 1990 forest inventory data, all fragments were composed of approximately 30% red maple (*Acer rubrum*), 20% white birch (*Betula papyrifera*), 20% balsam fir (*Abies balsamea*), 20% white spruce (*Picea glauca*), and 10% poplar (*Populus sp.*) with an average canopy height of 14 m. However, the 1990 forest inventory did not include hedgerows so information on covertype was not available for these areas.

3.1. Sites in Prince Edward Island National Park

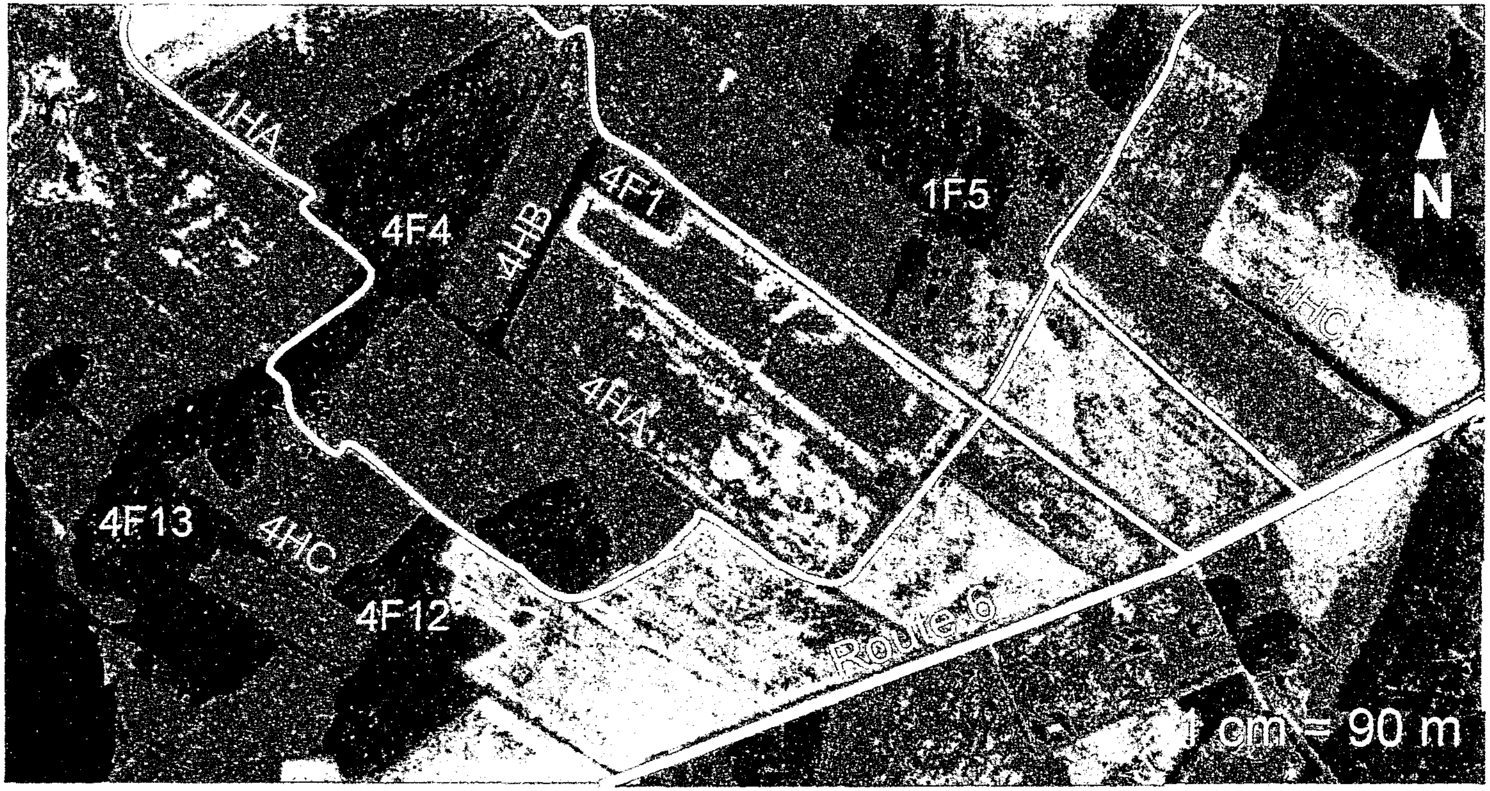
The first study area included two sites (Site 1 and Site 4) and was located within PEINP boundaries, approximately 1 km west of Cavendish, P.E.I. (46^0 23' 42" to 46^0 30' 48" N; 62^0 57' 50" to 63^0 28' 55" W). Prince Edward Island National Park is a narrow strip of coastline stretching approximately 40 km along the north shore of P.E.I. and encompasses an area of 25.90 km^2. The national park was first established in 1937 as a recreational seaside park and later became an important element of Parks Canada's representative systems plan (Keith 1996). Despite its relatively small area, PEINP consists of several distinctive habitat types including sand dunes, high coastal cliffs, woodlands, and wetlands (Prescott 1980). Topography within the park varies from flat areas to gently rolling hills (Prescott 1980). Vegetation occurs mainly in small communities with successional stages ranging from early old field to mature forest (Bateman and Prescott 1984). Almost all of the upland forest on P.E.I.

was once cleared and subsequent reforestation of old fields lead to forests dominated by white spruce, fir, and white birch. All mixed-wood and softwood forest are remnants of pre-park woodlots (Prescott 1980, Keith 1996).

Sites 1 and 4 were located on Federal Crown Lands managed by Parks Canada and are composed of farm fields interspersed with forested areas (Keith 1996). Management of these areas was intended to provide a buffer against adjacent development, contribute to the protection of the park resources and ecosystems, and used as a valuable recreational resource (Parks Canada 1998). Five forest fragments (0.01-0.560 km^2) as well as six hedgerows connecting these fragments were used for this study (Figure 3.2). In these sites, hedgerows ranged from 13 m to 450 m in length and width ranged from 11.3 m to 19.1 m (Table 3.1). The Homestead Trail, a popular hiking/biking trail, as well as several access roads also run through the study area. These features bisect and/or are present along the edge of several fragments and hedgerows.

The Federal Crown Lands encompassing Sites 1 and 4 were established in 1812 as the town of Bay View (P. McCabe, pers. comm). Land clearing in this area took place from the early 1800s until 1900. Fields surrounding fragments 1, 4, and 5 (Figure 3.2) were cleared in 1831 (P. McCabe, pers. comm.). After 1900, farmland in this area was slowly abandoned. Aerial photography

Figure 3.2. Sites 1 and 4 within the Prince Edward Island National Park including the forest fragments (1F5, 4F1, 4F4, 4F12, 4F13) and hedgerows (1HA, 1HB, 1HC, 4HA, 4HB, 4HC) examined during this study.



indicates that by 1935 present day forested stands and most hedgerows had assumed their current shape. Currently, agricultural fields within the Crown Lands are farmed by local leaseholders. Approximately 315 ha of Crown Land continues to be leased to area farmers for agriculture (Parks Canada 1998). Current agricultural use of crown lands within PEINP maintains the pastoral landscape and scenic vistas of the area.

3.2. Macphail Woods

The second study site (Site 2) was located in Orwell at the Macphail Homestead (46^0 09' 58" to 46^0 09' 35" N; 62^0 49' 40" to 62^0 49' 10" W). This site included the Macphail Woods Ecological Forestry Project (MWEFP), a private residence (owned by William and Margaret Wilton), and potato farmland owned by Andrew Speelman (Figure 3.3). Site 2 consisted of three hedgerows ranging from 290 m to 420 m long and 9.4 m to 31.0 m wide, as well as five connecting forest fragments (0.014-0.035 km^2; Tables 3.1 and 3.2).

The MWEFP was established in 1991 as a joint venture between the Environmental Coalition of P.E.I. and the Sir Andrew Macphail Foundation (G. Schneider, pers. comm.). This area includes three nature trails, demonstrations of windbreaks, forest restoration plots, and erosion control sites (MWEFP, http://www3.pei.sympatico.ca). Prior to establishment, the area encompassing the MWEFP was known as the Macphail Provincial Park. The provincial park

Figure 3.3. The Macphail Woods Ecological Forestry Project (Site 2) and surrounding areas including the forest fragments (F1, F2, F3, F4, F5) and hedgerows (HA, HB, HC) examined during this study. F2 and F3 were separated by a house and grassy area.

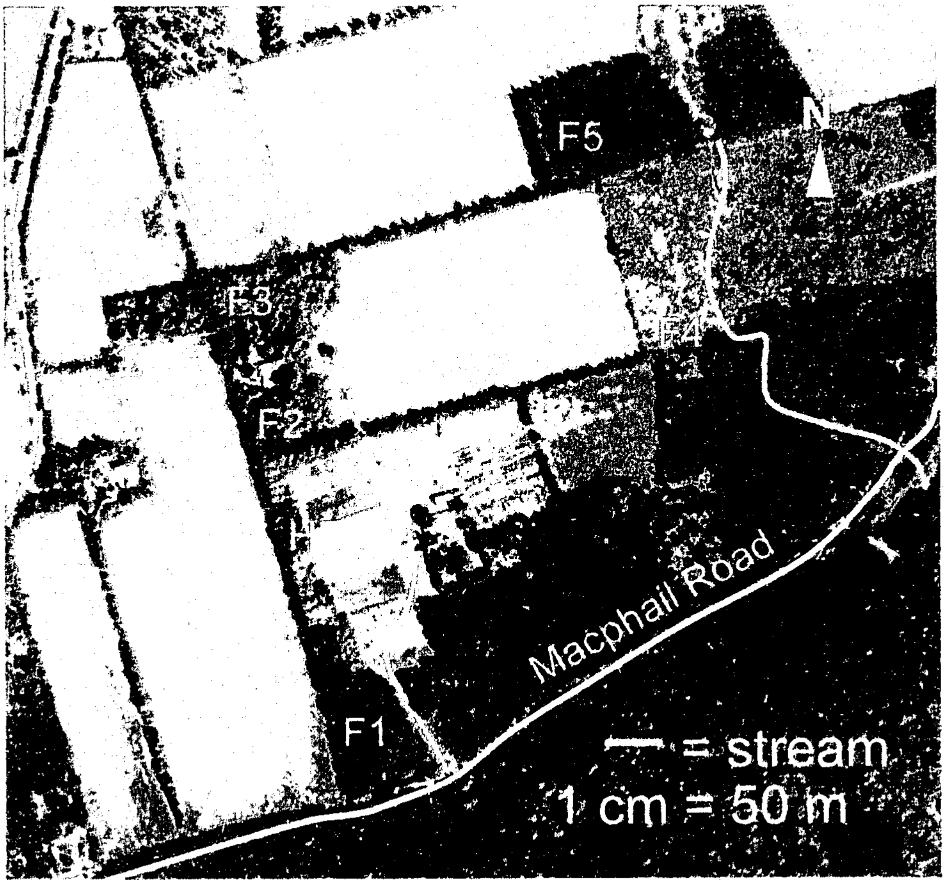


Table 3.1. Structural characteristics of hedgerows (H) labeled as A, B, C, D located within the Prince Edward Island National Park (Sites 1 and 4), Macphail Woods (Site 2), and Pleasant Grove (Site 3) study areas.

Site	Hedgerow	Length (m)	Width ± SD[a] (1 m height)	Width ± SD[a] (2 m height)
1	HA	250	12.88 ± 1.57	10.81 ± 3.38
	HB	130	13.71 ± 5.07	12.87 ± 6.09
	HC	490	13.58 ± 3.54	8.98 ± 5.20
2	HA	250	9.55 ± 1.71	9.18 ± 1.95
	HB	200	31.02 ± 7.30	30.88 ± 7.21
	HC	380	13.06 ± 4.16	12.81 ± 4.41
3	HA	720	12.74 ± 4.17	10.06 ± 4.54
	HB	140	15.38 ± 2.08	15.05 ± 2.57
	HC	130	16.23 ± 1.96	12.85 ± 5.96
	HD	70	14.32 ± 3.08	13.48 ± 1.12
4	HA	450	13.09 ± 4.03	10.74 ± 4.65
	HB	230	12.15 ± 1.71	11.37 ± 2.57
	HC	210	20.36 ± 8.98	17.85 ± 10.04

[a] SD = standard deviation.

Table 3.2. Structural characteristics of forest fragments within the Prince Edward Island National Park (Sites 1 and 4), Macphail Woods (Site 2), and Pleasant Grove (Site 3) study areas.

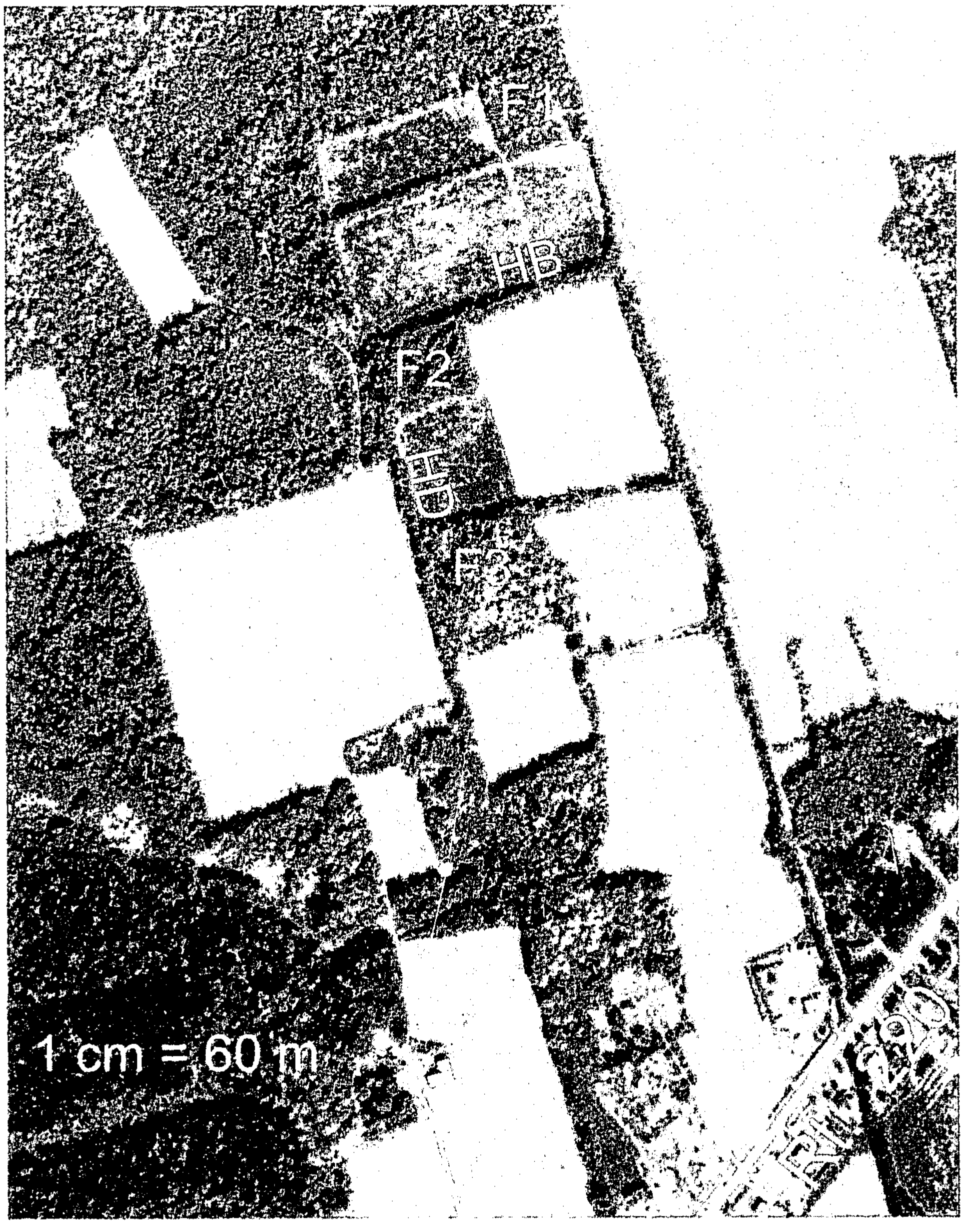
Site	Fragment	Area (km^2)	Perimeter (km)	A/P
1	F5	0.052	1.125	0.050
2	F1	0.018	0.595	0.030
	F2	0.014	0.507	0.028
	F3	0.015	0.564	0.027
	F4	0.035	1.202	0.029
	F5	0.023	0.671	0.034
3	F1	0.013	0.466	0.028
	F2	0.006	0.299	0.020
	F3	0.013	0.466	0.027
4	F1	0.010	0.704	0.014
	F4	0.065	1.720	0.038
	F12	0.560	1.505	0.037
	F13	0.058	1.181	0.049

was jointly managed by the Eastern District Forestry office and provincial parks foresters from 1978-1986. Prior to 1935, the study site was composed entirely of agricultural fields. All currently forested areas are a result of white spruce regeneration (B. Glen, pers. comm.). Several harvesting and planting activities occurred in this area during the late 1970s and early 1980s. In Fragment 1, regrowth of white spruce (*Picea glauca*), white pine (*Pinus strobus*), and Scotch pine (*Pinus sylvestris*) occurred naturally (B. Glen, pers. comm.). However, in 1981 foresters used tree crown release in this area to encourage growth of white pine. In 1978, fragment 4 was almost entirely clearcut and some white pine was left to regenerate the area. A small part of this fragment was not harvested and retained either for later harvesting, or as a buffer zone for the provincial campground (B. Glen, pers. comm.). Fragment 4 was replanted in 1979, initially with black spruce (*Picea mariana*) and later followed by beech (*Fagus grandifolia*), red maple, red oak (*Quercus rubra*), and white oak (*Quercus alba*). In 1980, Hedgerow B was widened as part of an observational plantation project. Yellow birch and butternut (*Juglans cinerea*) were planted in a section of old agricultural field adjacent to previously established hedgerows (Glen 1993). Radvanyi poison bait feeding stations and spiral tree guards were used to protect the new trees from meadow vole damage (Glen 1993). Currently there is no agricultural activity on the property. Fields bordering the east side of Hedgerow B and south side of Hedgerow C were last harvested for hay in the mid-1980s. However, fields on either side of hedgerow A and bordering the north side of Hedgerow C are currently used for potato production. During 2001, these fields were planted in soybeans. Aerial photography indicates that Fragment 5 was planted with white spruce and balsam fir (*Abies balsamea*) between 1980 and 1990. All hedgerows present in the area were first apparent in 1935.

3.3. Pleasant Grove

The third study site (Site 3) was located southwest of Pleasant Grove and the Highway 220-Suffolk Road intersection (46^0 21' 27" to $46^0$21' 46" N; $63^0$05' 16" to 63^0 05' 33 W). This site is on private land owned by John B. and Marian U. MacDonald (Figure 3.4). Site 3 contained four hedgerows ranging from 70 m to 720 m in length and 11.4 m to 15.22 m wide (Table 3.1). Three forest fragments (0.006-0.013 km^2) were also used (Table 3.2). Little information regarding prior land use activities is available for this area. According to aerial photography, the hedgerows were first established around 1935. Land use includes harvesting of hay from all the surrounding fields as well as timber from the fragments and hedgerows. Hay was harvested once during the study and timber was selectively harvested from Fragment 1 throughout the study.

Figure 3.4. The Pleasant Grove study site (Site 3) including the forest fragments (F1, F2, F3) and hedgerows (HA, HB, HC) examined during this study.

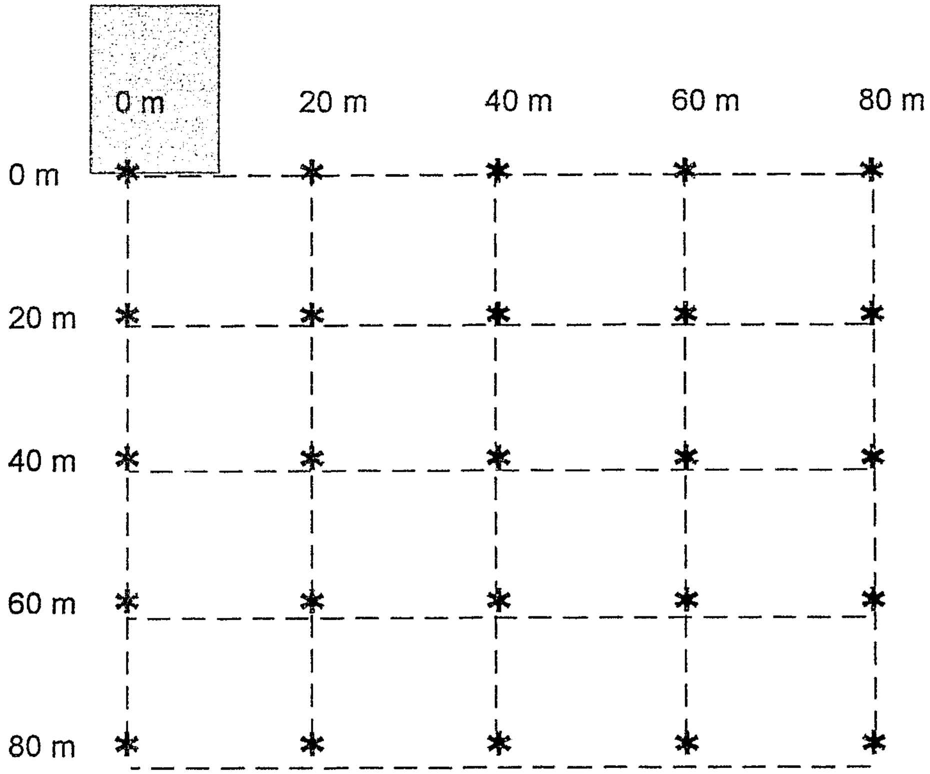


4. METHODS

4.1 Trapping Protocol

In each habitat fragment, trap stations containing one large Sherman live trap (50 x 62 x 165 mm) were placed at 20 m intervals in one of four grid configurations (*e.g.*, 4x4, 4x5, 5x5, 4x7) centered around the intersection of the hedgerow and fragment (Figure 4.1). Grid configurations were determined by the area and shape of the fragments. In some areas the grid encompassed the entire fragment, while in others it sampled a portion of the fragment (i.e., 0.6% to 80%). However, the maximum area covered by a trapping grid was 6400 m^2 regardless of fragment size. For each hedgerow, traps were placed in the center of the hedgerow vegetation at 10 m intervals throughout the length of the hedgerow. Based on visual observations, it was assumed that the hedgerows were not wide enough to contain both edge and interior habitat. Each site was trapped one time per month for three consecutive days. Each site was trapped at equal time intervals throughout the summer resulting in four trapping sessions per site. Within each site, all hedgerows and fragments were sampled simultaneously. Traps were set at approximately 1800 hrs on day one and checked twice daily (morning and evening) for the next two days. Each trap was baited with whole sunflower seeds. During the colder months (May and September), cotton balls were placed in each trap to provide insulation and reduce trap-related mortality. After the final trap check on day three, traps were

Figure 4.1. Arrangement of traps in forest fragment trapping grids.



☐ = hedgerow showing intersection of hedgerow and forest fragment
✱ = trap station
Area= 6400 m^2, 25 total trap stations

removed from the study area.

4.2 Specimen Processing

All animals were processed according to the guidelines listed in Animal Care Protocol number 01-021, which was approved in spring 2001. The trap number and trap location were recorded along with species and sex of the animal. Several standard measurements were taken. They include: body length (rostral aspect of nose to tail base, ruler, mm), body mass (Pesola scale, accuracy ± 2 g), tail length (mm), and hind foot length (mm). The reproductive condition of each animal was also assessed and individuals were classified as non-reproductive, scrotal, or having nipples present (Kunz *et al.* 1996). Females with nipples present and males with scrotal testes were considered reproductive adults. Juveniles and non-reproductive adults were categorized according to body mass (for chipmunks, <80 g=juvenile, >80 g=adult; *sensu* Bennett *et al.* 1994). Animals were tagged with one metal Monel size 1 fingerling tag in the pinnae of each ear. If an animal was already tagged, the tag numbers were recorded. If an animal was missing a tag, it was re-tagged. Animals with only one tag or ripped ears were considered to be missing a tag. Following processing, each animal was released at its point of capture. In order to reduce stress induced by handling, squirrels and chipmunks were anaesthetized using a small amount of ether administered on a cotton swab. Previous studies (*e.g.*, Lockie and Day 1964, Stoddardt 1970, Twigg 1975, Barnett and Dutton 1995) indicate that small mammals recover fully from anaesthesia within 7-12 minutes depending on body size. As long as the animals are not re-released in a "woozy" state, they do not suffer ill effects from this type of treatment.

4.3 Structural Characteristics of Hedgerows and Forest Fragments

Structural characteristics of hedgerows included length (m), width (m), and connectivity. Initially, the area of the selected fragments as well as the overall hedgerow lengths and widths were estimated using MapInfo:GIS. However, due to the ephemeral nature of hedgerows and the lack of current GIS information, hedgerow length and width were measured at the time of the study. Length was estimated by the number of traps in each hedgerow. Width was measured at 20 m intervals throughout the length of the hedgerow at 1 m and 2 m above the ground (*sensu* Bennett *et al.* 1994). The values were averaged to give an overall width at each height. The ratio width-length (W/L) was created to provide an indicator of hedgerow shape. A connectivity value was assigned to each hedgerow according to the number of fragments to which the hedgerow was connected. Based on connectivity, hedgerows were classified into three categories: 1= connected on two ends, 2= connected on one end, 3= unconnected. For each level of connectivity, small mammal abundance was calculated for each trap station within hedgerows. This measure of abundance was used to determine if the distance from connecting fragments (represented by the distance between trap stations and the edge of the forest fragment) influenced the abundance of small mammals. It was expected that distance from connecting fragments negatively influenced abundance. As distance from the fragment increases, small mammal abundance decreases. At a certain threshold distance, only individuals that use hedgerows as movement corridors or as living habitat are expected to be captured. Furthermore, it was expected that connectivity and distance from the fragment were related, with distance from the fragment having a stronger impact on abundance in less connected hedgerows.

Structural characteristics of forest fragments included fragment area (km^2), perimeter (km), and area-perimeter (A/P; km^2/km) ratio. Structural characteristics of forest fragments were determined after initial fragment selection using the Geographic Information System (GIS:ArcView, Environmental Systems Research Institute, 2000). Forest fragment outlines were provided by the P.E.I. Department of Agriculture and Forestry. Fragment size was calculated from polygon areas in the GIS database. Forest fragments were defined as areas of forest separated from large expanses of forest by agricultural fields, roads, streams, or land use activities (*e.g.*, timber harvesting, clear cuts).

In order to determine the effect of the surrounding landscape on small mammal communities in hedgerows, several variables were measured using

GIS:ArcView. The areas of surrounding agricultural fields were determined from polygon areas in the GIS database. The ratios hedgerow area-fragment area (AH/AF) and hedgerow area-field area (AH/Afield) determined the effect of the surrounding landscape on hedgerow use. The ratio hedgerow area-field area was also used as an indicator of forest fragment isolation, with hedgerows surrounded by large fields also being connected to smaller, more isolated forest fragments. Hedgerows connected to large forest fragments as well as fragments in close proximity to other forested areas, were expected to support a higher species richness and higher abundance of small mammals. However, small hedgerows embedded in large agricultural fields, as well as hedgerows connected to small or isolated forest fragments, may support fewer species in lower abundances due to increased edge effects and possibly less suitable habitat within these hedgerows.

4.4 Internal Characteristics of Hedgerows and Forest Fragments

Several hedgerow habitat characteristics were measured at each trap twice during the field season (early and late summer). Percent cover was estimated in 10% cover class intervals (0% to 100%) for trees (>4 m), tall shrubs (1.5-4 m), tall vines and creepers (1.5-4 m), shrubs (<1.5 m), vines and creepers (<1.5 m), grasses, herbs, litter/bare ground, and logs (*sensu* Bennett *et al.* 1994). Cover by grasses, herbs, and litter/bare ground was estimated using a 1 m^2 plot while all other above ground vegetation was estimated using a densitometer.

Litter depth (cm) and soil moisture were also measured. Soil moisture was measured with a soil moisture meter (1-3= dry, 3.1-7.9= moist, 8-10= wet). All woody plants were identified to the genus and species level and grouped based on height (>2 m and <2 m). For each trap station, all vegetation, litter, and soil characteristics were measured at five fixed points along a transect line which spanned the width of the hedgerow. The five points were evenly distributed along this transect line to include two edge points (where the hedgerow vegetation intersected with surrounding matrix) and three interior points, with the trap station being the center-most point. Woody plants >2 m in height that were located within 5 m of the transect line were identified to the species level. The habitat measurements from the two time periods were averaged to give values for each characteristic that represented the vegetation, litter, and soil characteristics at each transect point for the entire summer. Habitat characteristics at each transect point were averaged to give an overall value for each trap station. The habitat characteristics at the center-most point of the transect (the trap location) were also considered separately resulting in three values per habitat characteristic: average (AVG), standard deviation (SD), and center-most point (MID). A total of 33 variables were included in the analyses; 11 habitat characteristics with 3 values per characteristic.

The same habitat characteristics measured in hedgerows were also measured in each forest fragment. Each of the habitat variables was measured at each trap and then averaged to give an overall value characterizing the forest composition. All trees within a 2 m radius of each trap station were identified at the species level. The percentages of softwoods and hardwoods was calculated using GIS to give an overall picture of the canopy composition of each fragment.

4.5 Habitat Use and Distances Moved

Eastern chipmunks were the only species examined in this portion of the study. To determine habitat use, each individual was categorized according to the number of times it was trapped. These categories were: 1) permanent resident, 2) temporary resident, and 3) transient (*sensu* Bennett *et al.* 1994). Permanent resident animals included individuals captured in the same hedgerow or fragment during two or more trapping periods, temporary residents included individuals captured in a hedgerow or fragment during only one trapping session even if the individual was trapped several times during that session, and transients included animals captured in a hedgerow or fragment only one time throughout all trapping sessions (*sensu* Bennett *et al.* 1994). Within each of these categories, individuals were grouped according to reproductive condition and age.

Individual distances moved within fragments and hedgerows were determined from trapping data. While each animal's exact paths cannot be established using this method, trapping data gives a comprehensive representation of the distance each individual moves within the respective habitats. Distances were only calculated for individuals captured at least three times in the same habitat. Following Koeppl *et al.* (1977), we calculated the distance each individual traveled by determining the distance moved between successive capture locations ($d_i = [(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2]^{1/2}$), the mean sequential distance each individual traveled, ($l_k = (\sum d_i) / n\text{-}1$), and the weighted population home-range index. Sequential distance is the minimum distance the individual actually travels between captures and the weighted home-range index is based on the assumption that the reliability of the contribution of each individual to the population index varies directly with its sample size. These indices were used to compare the average distance individuals moved within each type of habitat. It was expected that individuals moved longer distances in hedgerows than forest fragments.

4.6 Linear Continuity of Hedgerows

In addition to habitat variables, the number of gaps present in the hedgerow were also measured. Gaps were lengths of hedgerow >5 m that lacked trees in the canopy. The length of each gap was measured and the vegetation species present were identified. Gaps were categorized into two groups, 1) those with shrubs, grasses, or herbs in the understory, and 2) those that lacked all ground cover (i.e., farm roads). The proportion of gaps along each hedgerow was calculated (total length of gaps / length of hedgerow). The proportion of gaps in each category was also calculated for each hedgerow.

4.7 Statistical Analyses

Objective 1: Species richness and abundance within hedgerows

Small mammal species richness was calculated for each hedgerow and forest fragment by counting the different species found to occur in these areas. The total number of captures per species in each hedgerow was tallied and used as a relative measure of abundance for each species. The Shannon-Weiner index of diversity, $H' = \sum (p_i)(\log_2 p_i)$, where p_i is the proportion of individuals belonging to the ith species (Shannon and Weiner 1949), was calculated for small mammals, overstory trees (trees >2 m), and understory (shrubs <2 m) using the software package Ecological Methodology (Krebs 2000). We also calculated the abundance of small mammals at each 10 m distance from the edge of the connecting fragments. This was used to determine if the distance from connecting fragments influenced the abundance of small mammals. It was expected that distance was negatively associated with abundance and that this would vary depending on hedgerow connectivity and total hedgerow length.

For each hedgerow, percent trapping success was also calculated and used to indicate the effect of disturbance on abundance. In areas where disturbance is high, trapping may indicate lower small mammal abundance than is actually present. Disturbed traps are less effective than undisturbed traps and are less likely to capture small mammals than undisturbed traps. Trapping success was calculated for all morning and all evening trapping sessions as well as for the entire field season (% success = # animals caught / # traps working). At each trap check, traps were categorized into one of four groups (i.e., undisturbed, sprung, moved, containing animal) to calculate trapping efficiency. Traps that were undisturbed or contained an animal were considered to be 100% effective, traps moved but not sprung were 50% effective, and traps sprung but not containing an animal were 0% effective. Working traps included those that were 100% effective as well as those that were 50% effective.

Normality was tested using the Kolmogorov-Smirnov normality test. Variables that were not normal were log-transformed and re-tested for normality. Pearson correlation and linear regression analyses were used to examine relationships between species richness, species diversity, and total abundance of small mammals and the structural characteristics of hedgerows. We also used multiple-regression analysis to develop models that best explained variability in the abundance of small mammals.

Objective 2: Microhabitat and Landscape Variables

To standardize for trapping effort, relative abundance (P_R) was calculated as the total number of captures (P_T) divided by trapping effort and multiplied by 100: $P_R = [(P_T / \text{TNT}) \times 100]$, where TNT is the total number of trap nights (Silva 2001). Species richness was calculated for each hedgerow and forest fragment by counting the different species found to occur in these areas. Percent trapping success was calculated for all morning trapping sessions, all evening trapping sessions, and the entire field season (morning and evening combined). The Shannon-Weiner index of diversity was calculated for each hedgerow using the software package Ecological Methodology (Krebs 2000).

All data were tested for normality using the Kolmogorov-Smirnov goodness of fit test. Pearson correlations were used to examine relationships between small mammal community variables (i.e., species richness, species diversity, abundance of small mammals) and internal and structural hedgerow habitat variables. Principle components analysis (PCA) was performed on correlation matrices to reduce the number of hedgerow habitat characteristics. PCA transforms the original set of variables into a smaller set of combinations that accounts for most of the variance in the original set (Dillon and Goldstein 1984). The purpose of this method was to determine factors or principle components that explain as much of the variation in the data as possible with as few factors as possible (Dillon and Goldstein 1984). The new variables (factors) are linear combinations of the original variables (Williams 1993). PCA factors with eigenvalues >1 were retained and factor loadings with magnitudes greater than

0.5 were considered biologically significant (Dillon and Goldstein 1984). Factors with the highest loadings were used to describe each component. Relationships between PCA factors and small mammal community variables were determined using stepwise multiple regression analyses. Within each PCA factor, the three habitat characteristics with the highest factor loadings were also used in stepwise multiple regression analyses. Pearson correlations and stepwise multiple regression analyses were used to examine relationships between forest fragment habitat characteristics and small mammal community variables.

Objective 3: Hedgerow use and distance moved

Eastern chipmunks were the only species included in this portion of the analysis. To standardize for trapping effort, relative abundance (P_R) was calculated as total population size (P_T) divided by trapping effort and multiplied by 100: $P_R = [(P_T / TNT) \times 100]$, where TNT is the total number of trap nights (Silva 2001). All data were tested for normality using the Kolmogorov-Smirnov goodness of fit test. The overall average body mass (g) of eastern chipmunks was compared between hedgerow and fragment habitats separately using two-sample t-tests (when $p>0.05$, $\mu_1 = \mu_2$). The average body mass (g) of males and average mass (g) of females was compared separately between habitats. Residency status (i.e., permanent resident, temporary resident, transient) was compared between hedgerow and fragment habitats using two-way ANOVA.

Each of the three measures of distance traveled were compared separately between fragment and hedgerow habitats using two sample t-tests (when $p>0.05$, $\mu_1 = \mu_2$).

5. SMALL MAMMAL ABUNDANCE AND SPECIES RICHNESS WITHIN HEDGEROWS ON PRINCE EDWARD ISLAND

5.1 Introduction

Hedgerows, small strips of vegetation separating farm fields, are a common and widespread landscape feature on Prince Edward Island. The island is located in the Gulf of St. Lawrence and encompasses an area of approximately 5660 km^2 (Weighs 1995). The original forests of Prince Edward Island are considered part of the Acadian Forest Region, characterized by hardwoods including sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), and beech (*Fagus grandifolia*) (Round Table Report 1997). During the last three centuries, land was cleared for farming and timber was harvested for lumber and shipbuilding. The rate of deforestation peaked in the early 1900s, but deforestation has continued throughout the century for potato production and farming (Johnston 2000). The Acadian forest was replaced by softwoods, and extensive agriculture and timber harvesting practices have resulted in forest fragments of early successional, even-aged forest dominated by white spruce *(Picea glauca)* (Round Table Report 1997).

Historically, most hedgerows in Prince Edward Island were a single or double row of trees that established themselves along fencelines (Pharoah 1983, Stewart 1999). In the 1970's and 1980's, maintenance of hedgerows by landowners declined and government incentives to remove hedgerows began resulting in a net loss of hedgerows. In addition, hedgerows in general are often under threat from mechanized farming and are removed in order to facilitate field expansion in eastern North America (Baudry *et al.* 2000). Currently, however, the benefits of hedgerows for soil conservation, crop protection, and aesthetic appeal are again being recognized (Round Table Report 1997). Furthermore, hedgerows are often the only links between forest fragments in many areas of Prince Edward Island.

Agricultural landscapes isolate populations of woodland species in habitat patches by reducing the amount of forest habitat and increasing matrix habitat (i.e., crops) that may be unsuitable for many woodland species (Henderson *et al.* 1985). Hedgerows provide permanent vegetation in contrast to arable land, which loses vegetation after harvest (Tischendorf and Wissel 1997). Hedgerows may provide extended habitat for small mammals and may act as corridors between isolated habitats in agricultural landscapes (Yahner 1982, Yahner 1983, Henderson *et al.* 1985, Wegner and Merriam 1990, Bennett *et al.* 1994, Wauters *et al.* 1994, Downes *et al.* 1997, Kotzageorgis and Mason 1997, Henein *et al.* 1998, Laurance 1999). For example, hedgerows provide breeding habitat as well as movement corridors for the eastern chipmunk (*Tamias striatus*) (Henderson *et al.* 1985, Bennett *et al.* 1994). Furthermore, the loss of hedgerows or a reduction in their quality may have detrimental effects on population size, population persistence, and population variability of eastern chipmunks (Henein *et al.* 1998). Hedgerows may also be important for other small mammal species occurring in Prince Edward Island's natural habitats, such as the southern red-backed vole (*Clethrionomys gapperi*), short-tailed shrew (*Blarina brevicauda*), and masked shrew (*Sorex cinereus*) (Yahner 1983).

Structural features of hedgerows such as length, width, and connectivity, may influence species richness, abundance, and patterns of hedgerow use by small mammals. Species richness has been positively associated with both the area and perimeter of farmstead shelterbelts (Yahner 1983). Tischendorf and Wissel (1997) tested the capability of hedgerows as corridors using computer simulations and found that hedgerow width was positively correlated with the likelihood that an individual would reach an isolated habitat. However, Henderson *et al.* (1985) found that hedgerow width was not a significant determinant of eastern chipmunk breeding habitat, with hedgerows as narrow as 3 m being used as breeding habitat. In Australia, Laurence and Laurence (1999) found that linear habitats of moderate width (20-80 m) were used by five of the six mammalian species studied. Fitzgibbon (1997) found that the effect of connectedness, hedgerow length, and the number of hedgerows on small mammals was species specific.

Although recent studies have investigated the effects of fragmentation on the abundance and species richness of small mammals in forest fragments on Prince Edward Island (Silva 1999, Silva *et al.* 2000, Silva 2001), little is known regarding the use of hedgerows by these organisms. However, Silva (2001) found that linear fragments in Prince Edward Island National Park may sustain small mammal communities with a diversity similar to that found in other shaped fragments. Therefore, hedgerows may be as important as forest fragments for providing habitat for small mammal communities. This highlights the importance of further investigation into the role of hedgerows on Prince Edward Island. Furthermore, hedgerows are ephemeral on Prince Edward Island and the effects of hedgerow removal on wildlife is essentially unknown.

The purpose of this portion of the study was to assess the abundance and species richness of small mammals found in hedgerows on Prince Edward Island. Previous surveys indicate that 16 species of small mammals are present on the island (Prescott 1980, Bateman and Prescott 1984, Silva 1999, Silva *et al.* 2000, Silva 2001). These include five insectivores, 10 rodents, and one carnivore. However, due to the specific habitat requirements of each species, only 11 species were expected to be encountered during this study. Of the two insectivores, the masked shrew has been found to be the most widespread species within Prince Edward Island National Park (Silva *et al.* 2000). The eastern chipmunk has been found to be both widespread and abundant within the Prince Edward Island National Park (Silva *et al.* 2000) and may also be abundant at other sites on the island. Other rodents expected to be found during this study include the American red squirrel (*Tamiasciurus hudsonicus*), southern red-backed vole, meadow jumping mouse (*Zapus hudsonius*), and deer mouse (*Peromyscus maniculatus*). The northern flying squirrel (*Glaucomys sabrinus*) and the woodland jumping mouse (*Napaeozapus insignis*) are expected within the surrounding forested areas, but their occurrence in hedgerows is uncertain. Finally, the short-tailed weasel (*Mustela erminea*) has been previously captured in linear habitats within the Prince Edward Island National Park (Silva 2001), so it is expected to also occur in hedgerows.

5.2 Methods

Study areas

This study was conducted in three sites located in central Prince Edward Island. A total of 13 hedgerows were studied. All study sites (Prince Edward Island National Park, Macphail Wood, Pleasant Grove) shared three main characteristics: 1) forest fragments of similar cover type, 2) low intensity agriculture surrounding the fragments, and 3) a network of at least three hedgerows that varied in length between 70 m and 720 m and width between 9.37 m and 30.95 m (Table 5.1). Cover type of the forest fragments was estimated using 1990 forestry inventory data (Prince Edward Island Department

Table 5.1. Structural characteristics of hedgerows examined during this study.

Site[a]	Hedgerow	Length (m)	Width ± SD[b] (1 m height)	Width ± SD[b] (2 m height)	Connectivity[c]	Understory (H')[d]	Overstory (H')[d]
1	HA	250	12.88 ± 1.57	10.81 ± 3.38	2	2.19	2.41
	HB	130	13.71 ± 5.07	12.87 ± 6.09	2	2.30	2.35
	HC	490	13.58 ± 3.54	8.98 ± 5.20	3	2.74	2.11
2	HA	250	9.55 ± 1.71	9.18 ± 1.95	2	2.07	2.79
	HB	200	31.02 ± 7.30	30.88 ± 7.21	1	2.94	2.70
	HC	380	13.06 ± 4.16	12.81 ± 4.41	1	2.26	2.29
3	HA	720	12.74 ± 4.17	10.06 ± 4.54	2	2.01	2.37
	HB	140	15.38 ± 2.08	15.05 ± 2.57	1	3.35	2.30
	HC	130	16.23 ± 1.96	12.85 ± 5.96	1	2.55	1.93
	HD	70	14.32 ± 3.08	13.48 ± 1.12	2	2.37	2.22
4	HA	450	13.09 ± 4.03	10.74 ± 4.65	2	2.25	2.31
	HB	230	12.15 ± 1.71	11.37 ± 2.57	1	2.54	2.25
	HC	210	20.36 ± 8.98	17.85 ± 10.04	1	2.03	2.12

[a] Sites 1 and 4 refer to the Prince Edward Island National Park, Site 2 refers to the Macphail Woodlot, and Site 3 refers to the Pleasant Grove study site.

[b] SD = standard deviation.

[c] 1= connected on both ends, 2= connected on one end, 3= no connections.

[d] $H' = -\sum (p_i)(\log_2 p_i)$, where p_i is the proportion of total samples belonging to the ith species (Shannon and Weiner 1949).

of Agriculture and Forestry) coupled with Geographic Information Systems (MapInfo:GIS). According to 1990 forest inventory data, all forest fragments were composed of 30% red maple (*Acer rubrum*), 20% white birch (*Betula papyrifera*), 20% balsam fir (*Abies balsamea*), 20% white spruce (*Picea glauca*), and 10% poplar (*Populus sp.*), with an average canopy height of 14 m. Forest inventory data was not available for hedgerows, however, their canopy composition ranged from predominantly softwood (i.e., white spruce) to a mixed-wood type containing red maple (*Acer rubrum*), white birch, and poplar. All hedgerows selected for this study contained a mature white spruce backbone characteristic of hedgerows found on Prince Edward Island (Pharoah 1983). Understory vegetation was highly variable and included shrubs (*e.g.*, *Rubus idaeus*, *Crataegus sp.*, *Rosa virginiana*, *Kalmia angustifolia*), grasses, herbs (*e.g.*, *Cornus canidensis*, *Aralia nudicaulis*, *Vaccinium angustifolium*), and bare ground. Hedgerow vegetation that occurred along fencelines between fields provided additional habitat and formed corridor networks between forest fragments. The surrounding farm fields were used primarily for hay and barley production. However, fields at the Macphail site were also used for potato production.

Trapping procedures

Small mammals were trapped between May and September 2001. Each site was trapped monthly for three consecutive days (*sensu* Silva 1999, Silva *et* *al.* 2000, Silva 2001). Large Sherman live-traps (50 x 62 x 165 mm) were baited with sunflower seeds and contained cotton bedding in the colder months. In the hedgerows, trap stations were placed at 10 m intervals throughout the length of the hedgerow, with one trap per station located mid-width in the hedgerow vegetation. Traps were checked twice daily, morning and evening. Captured animals were identified, ear tagged (with Monel type tags), and body mass (g), body length (mm), tail length (mm), and hind foot length (mm) were recorded. The reproductive condition of each animal was noted and classified as non-reproductive, scrotal, or nipples present. In order to reduce stress induced by handling, squirrels and chipmunks were anaesthetized using a small amount of ether administered on a cotton swab. Traps that were undisturbed or contained an animal were considered to be 100% effective, traps moved but not sprung were rated as 50% effective, and traps sprung but not containing an animal were 0% effective.

Structural characteristics of hedgerows

Preliminary estimates of length and width of hedgerows were obtained from GIS. However, due to the ephemeral nature of hedgerows on Prince Edward Island, final measures of hedgerow length were approximated using the number of traps present in a hedgerow. Hedgerow width was measured every 20 m at 1 m and 2 m above ground (*sensu* Bennett *et al.* 1994). These measurements were averaged to give an overall width for each hedgerow. The ratio width-length (W/L) was calculated to provide a general indicator of hedgerow shape. Connectivity was calculated by counting the number of fragments to which the hedgerow was connected (1= connected on two ends, 2= connected on one end, 3= unconnected).

Macrohabitat condition was assessed by examining the vegetation composition of the hedgerows. A transect line spanning the width of the hedgerow was established at each trap location (*sensu* Bennett *et al.* 1994). All woody species occurring within 5 m of the transect were identified to genus and species and grouped by height (<2 m and >2 m). Hedgerows with high vegetative species diversity may contain a higher small mammal species richness due to the increased availability of food resources.

Analyses

Species richness was calculated for each hedgerow and forest fragment by counting the different species found to occur in these areas. The total number of captures per species in each hedgerow was tallied and used as a relative measure of abundance for each species. For each hedgerow, percent trapping success was calculated for the morning, evening, and the entire field season. The Shannon-Weiner index of diversity, $H' = \sum (p_i)(\log_2 p_i)$ where pi is the proportion of individuals that belong to the ith species, (Shannon and Weiner 1949) was calculated for small mammals, overstory trees (trees >2 m), and understory (shrubs <2 m) using the software package Ecological Methodology (Krebs 2000). We also calculated the abundance of small mammals at each 10 m distance from the edge of the connecting fragments. This was done to determine if the distance from connecting fragments influenced the abundance of small mammals. It was expected that distance was negatively associated with abundance and that this would vary depending on hedgerow connectivity.

Data that did not fit the assumption of normality (Kolmogorov-Smirnov goodness of fit test) were log-transformed. Relationships between species richness, species diversity, and total abundance of small mammals and the structural characteristics of hedgerows were examined using the Pearson correlation and linear regression analyses. We also used multiple-regression analysis to develop equations to explain variability in abundance of small mammals.

5.3 Results

Abundance and species richness

A total of 355 small mammals representing 221 individuals from 11 different species were captured in approximately 5066 trap nights (Table 5.2). Two hedgerows contained 8 species. The eastern chipmunk was the most abundant and widespread species, accounting for 77.5% of captures in 12 hedgerows. Although American red squirrels occurred in seven hedgerows,

Table 5.2. Total captures of small mammals in hedgerows within the Prince Edward Island National Park (Sites 1 and 4), Macphail Woodlot (Site 2), and Pleasant Grove (Site 3) study areas.

	Site 1			Site 2			Site 3				Site 4		
	HA	HB	HC	HA	HB	HC	HA	HB	HC	HD	HA	HB	HC
Tamias striatus	12	23	47	10	6	29	57	10	5		29	27	20
Tamiasciurus hudsonicus			2		2	2	17			2	1	1	0
Peromyscus maniculatus	3		1	2			4	1				4	6
Sorex sp.			1	1	1		2				1		
Zapus hudsonius		1	3				3				3		
Blarina brevicauda		1	5				2	1					
Mustela erminea	2		2								6		
Clethrionomys gapperi				2			2	1					
Glaucomys sabrinus						3	1						
Microtus pennsylvanicus			2			1							
Napaeozapus insignis		5											

they were only abundant in one site (Table 5.2).

Hedgerow quality

There was considerable discrepancy between the abundance of eastern chipmunks and the abundance all other species trapped in the hedgerows. Due to this difference, we analyzed chipmunks separately from the other small mammal species. Length explained 85.4% of the variation in abundance of small mammals. The abundance of chipmunks and the abundance of other species was positively correlated with length, explaining 80.6% (p=0.001, n=13) and 84.3% (p=0.001, n=13) of the variation, respectively. When the longest hedgerow was excluded (length >600 m), 71.2% of the variation in the abundance of others and 70.5% of variation in abundance (p=0.001, n=12) was explained by length. Multiple regression analyses found that 86% (p=0.001, n=13) of the variation in the abundance of other small mammal species was best explained by length and connectivity.

Small mammal community variables were not significantly correlated with hedgerow width (p>0.05). Linear regression analyses indicated that 77.1% (p=0.001, n=13) of the total variation in the abundance of other species was explained by W/L, with most hedgerows being long and narrow. However, when the longest hedgerow (length>600 m) was excluded from the analyses, a stronger relationship was found between species richness and W/L (r^2= 0.561, p=0.001, n=12) than between the abundance of other species and W/L (r^2= 0.477, p=0.001, n=12).

Twelve of the 13 hedgerows studied were connected to a forest fragment either on one end or both ends (Table 5.1). Species richness in hedgerows was positively associated with connectivity values. This may imply that hedgerows with fewer connections to forest fragments maintain the highest richness. A negative relationship was found between the abundance of small mammals in hedgerows and the distance from the adjacent forest fragment. In hedgerows connected at both ends, the abundance of chipmunks and other species were similarly affected by distance (r^2= 0.253, p=0.028; r^2= 0.262, p=0.025, respectively). However, for hedgerows connected at one end distance explained more variation in the abundance of chipmunks (r^2= 0.304, p=0.001) than variation in other species (r^2= 0.072, p=0.023).

Small mammal community variables, such as species richness, species abundance, and species diversity, were not significantly correlated with overstory diversity (p>0.05). Sixty-two percent of the variation in the abundance of other species (p=0.001, n=13), 59.9% (p=0.002, n=13) of variation in total captures, 55.0% (p=0.004, n=13) of variation in abundance of chipmunks, and 47.5% (p=0.009, n=13) of the variation in species richness was explained by understory diversity. However, when the site with the highest diversity was excluded from the analyses, all of the relationships became non-significant (p>0.05, n=12).

5.4 Discussion

Over the past three centuries, many habitats on Prince Edward Island have been severely fragmented by agricultural and forestry activities, and few areas of continuous forest habitat still exist on the island. Hedgerows have had a long standing influence on the landscape of Prince Edward Island providing many benefits to landowners (Round Table Report 1997). They may also benefit wildlife by providing additional habitat as well as acting as corridors through the agricultural landscape. Overall, our results suggest that hedgerows sustain small mammal communities similar to those found in forest fragments. All eleven small mammal species that commonly occur within forest fragments on Prince Edward Island were also captured within hedgerows. The two longest hedgerows (Site 1-HA and Site 3-HA) contained a similar species richness to that previously determined for larger forest fragments within Prince Edward Island National Park (Silva 2001). One explanation for this is that long hedgerows (>400 m) provide a variety of habitats similar to habitat variation found in forest fragments. Small mammal species richness has been associated with hedgerow size and microhabitat complexity (Yahner 1983). Although the diversity of trees and shrubs was not significantly related to any small mammal community variables in my study, long hedgerows may contain other microhabitat features (i.e., % canopy and ground cover, soil moisture) that are similar to the habitat conditions found in forest fragments. Yahner (1983) found that a higher diversity of small mammals was found in hedgerows characterized by habitat features that simulated or characterized those occurring in mature natural habitats. Further investigation is needed regarding the relationship between microhabitat features of hedgerows and small mammal abundance within hedgerows on Prince Edward Island.

The eastern chipmunk was the most abundant and widespread species captured in hedgerows. This result was not surprising, considering that eastern chipmunks have also been found to occur in many habitat types within the Prince Edward Island National Park (Silva *et al.* 2000, Silva 2001). However, our results contradict historical information suggesting that while eastern chipmunks occur across Prince Edward Island, they do not reach high abundances (Bateman and Prescott 1984). Hedgerows may be particularly important for maintaining eastern chipmunk populations within agricultural landscapes in Prince Edward Island. Other similar studies in Ontario, Canada found that eastern chipmunks use hedgerows as breeding habitat and as movement corridors (Henderson *et al.* 1985, Bennett et. al 1994). Hedgerows are also important for maintaining viable populations of eastern chipmunks inhabiting agricultural landscapes (Henein *et al.* 1998). Hedgerows may be particularly important for eastern chipmunks as well as other members of the family Sciuridae (i.e., the American red squirrel and northern flying squirrel), by functioning as corridors for movement between forest fragments. Within Prince Edward Island National Park, eastern chipmunks do not appear to make use of the surrounding agricultural fields (Silva 1999), which are readily available and oftentimes more accessible for movement than hedgerows. Other studies have shown that eastern chipmunks seldom move through grassy fields or crops, even though that type of movement is possible (*e.g.*, Wegner and Merriam 1979, Merriam 1984, Bennett 1994). Therefore, eastern chipmunks may almost exclusively use hedgerows for movement between forest fragments. Further investigation into the movement patterns of chipmunks in hedgerows is needed to determine if hedgerows serve as corridors for this species or are simply used as additional habitat for foraging.

Several other small mammal species were captured within hedgerows, although none reached high abundances. One explanation for this may be that the trapping design used within hedgerows was not effective for capturing a wide variety of species. Only Sherman live-traps were used in this study and this may have resulted in an underestimation of trap shy species. A combination of live-traps and pitfall traps may have resulted in a more robust estimation of insectivores and small rodents such as the meadow jumping mouse and woodland jumping mouse.

Hedgerow width was not significantly correlated with any of the small mammal community variables. One explanation for our findings is that within this study there was not sufficient variation in hedgerow width. Average width varied from approximately 10 m to 20 m, with only one hedgerow wider than 20 m. Wider hedgerows may not be feasible when considering small mammal conservation on Prince Edward Island, due to the fact that the primary function of hedgerows is to provide benefits to landowners.

From a conservation perspective, an interesting result from this study was the positive relationship between connectivity (i.e., connected on one or both ends) and small mammal community variables. Small mammal species richness and diversity varied with the level of connectivity. One explanation for this could be that hedgerows that are connected on both ends are used more as movement corridors than additional foraging or breeding habitat. At any specific time, species richness in hedgerows connecting forest fragments may be lower than in isolated hedgerows, reducing the probability of capturing individuals from many species. Small mammals may use connecting hedgerows strictly as movement pathways between forest fragments while other hedgerows may be used as extended portions of their home-range or as additional foraging areas (*e.g.*, Wauters *et al.* 1994). Furthermore, isolated hedgerows may restrict woodland small mammals to hedgerow habitat, increasing the probability of capturing individuals from many species. Our results also indicate that the distance from the nearest fragment negatively influenced the abundance of chipmunks as well as the abundance of other species at both high and low levels of connectivity. It is possible that at a certain distance from the forest fragment, hedgerows may no longer be used by small mammals as extended habitat. This distance may be determined by home-range size of the species as well as other factors including increased predation risk when moving further from the connecting fragment. Several weasels were captured in hedgerows and the presence of predators within hedgerows may influence the distance from the fragment that an individual is willing to move.

Our findings show that hedgerows may be an important habitat resource for small mammals, especially the eastern chipmunk, occurring in highly fragmented agricultural landscapes of Prince Edward Island. However, since this study was limited to one field season and each site was only sampled for three days per month, small mammal abundance recorded within hedgerows may not adequately reflect actual small mammal abundance within hedgerows. Longer trapping sessions may have resulted in higher small mammal abundances, especially for species that were captured in low abundance. Also, discrepancies between abundances of eastern chipmunks and abundances of other small mammal species may have been due to the calculation of abundance which included captures and recaptures. This may have resulted in an overestimation of chipmunks, which do not seem to have an aversion to trapping, and an underestimation of other species that are trap shy. Nevertheless, our results show that 11 of the 15 species known to occur within forest fragments on Prince Edward Island also occur within hedgerow habitat, demonstrating that hedgerows are an important habitat resource for small mammals on the island. Little is known regarding the impacts of hedgerow removal on adjacent small mammal communities. Although this study does not address the issue of hedgerow removal, our findings provide evidence showing that hedgerows may be important for maintaining viable populations of small mammals. A long-term study involving more hedgerows is needed to determine whether hedgerows are used as habitat and/or corridors. A better understanding of these issues would further improve hedgerow management and conservation.

6. THE INFLUENCE OF HABITAT CHARACTERISTICS OF HEDGEROWS AND FOREST FRAGMENTS ON SMALL MAMMAL COMMUNITIES ON PRINCE EDWARD ISLAND

6.1 *Introduction*

Fragmentation has been studied in many ecosystems worldwide and at a variety of spatial scales (da Fonseca and Robinson 1990, Robinson *et al.* 1992, Yahner 1992, Dunstan 1996, Henein *et al.* 1998, Laurance and Laurance 1999, Lindenmayer *et al.* 1999, Lynam and Billick 1999, Nupp and Swihart 2000). Although habitat fragmentation occurs naturally resulting in landscape heterogeneity, anthropogenic fragmentation results in a reduction of native habitat and an increase in matrix habitat. In any landscape, there are varying degrees of fragmentation. Some landscapes are composed of small amounts of matrix habitat embedded in nearly continuous native habitat, while other landscapes are characterized by isolated fragments of native habitat embedded in large expanses of matrix habitat (Lord and Norton 1990, Merriam 1995). In landscapes that are highly fragmented, such as agricultural landscapes, the reduced size and increased isolation of the remaining native habitat fragments strengthen the species decline initiated by habitat loss (Andren 1994). Species that require large, continuous habitats as well as species that are sensitive to the modified micro-environment due to edge effects are often lost in highly fragmented landscapes (Forman and Godron 1981). However, some studies have found that fragmentation does not always lead to detrimental effects on all species involved (Yahner 1992, Dunstan and Fox 1996, Nupp and Swihart 1996, Bayne and Hobson 1998, Bayne and Hobson 2000). For example, Bayne and Hobson (1998) found that American red squirrels (*Tamiasciurus hudsonicus*) and northern flying squirrels (*Glaucomys sabrinus*) were more abundant in farm woodlots than continuous forests.

One of the most important effects of habitat fragmentation is isolation of populations. Isolation is most often caused by linear constructions, such as roads and power lines, and intensive agricultural land use (Mader 1984). Characteristics of landscape structure, such as size, shape, and quality of patches, presence of dispersal routes, quality of dispersal routes, and spatial configuration of the components of the landscape (i.e., spatial arrangement of specific elements), are important factors to consider when determining the effects of isolation on species and populations (Fahrig and Merriam 1994). Rosenberg *et al.* (1997) found that small populations of organisms isolated by fragmentation exhibit higher extinction rates. Fahrig and Merriam (1985) found that populations of white-footed mice (*Peromyscus leucopus*) in isolated woodlots had lower growth rates than mice in connected woodlots. Furthermore, the frequency and persistence of local extinctions of white-footed mice depended on the degree to which individual patches were isolated from one another. Corridors have been proposed as a tool to enhance connectivity between habitat fragments and mitigate the effects of isolation on wildlife populations.

Corridors are most commonly proposed as management tools in situations where only isolated fragments of habitat remain and when corridors can be expected to increase movement of species across the landscape (Merriam 1995). However, habitat requirements of species are variable and the high degree of variation in the results of corridor studies has led to a lack of consensus as to what makes a corridor beneficial (Perault and Lomolino 2000). External features of corridors describe the form of the corridor and its relationship with adjacent patches, while internal characteristics determine corridor function (Forman 1991). Both external (*e.g.*, length, connectivity, presence of gaps) and internal features (*e.g.*, width, adjoining land use, vegetation composition) of corridors may affect their function in the landscape. Danielson and Hubbard (2000) found that oldfied mice (*Peromyscus polionotus*) may use wide corridors (32 m) as additional habitat rather than dispersal corridors. Ruefenacht and Knight (1995) found that the number of gap crossings and amount of corridor movement by deer mice (*Peromyscus maniculatus*) was positively associated with tree density in corridors and gaps. Gaps were defined as 10 m wide areas where all vegetation ≤7 m diameter breast high was removed (Ruefenacht and Knight 1995). In Ontario (Canada) Bennett *et al.* (1994) found that the abundance of resident eastern chipmunks

(*Tamias striatus*) in corridors was best predicted by features of the habitat while the abundance of transients was best predicted by a combination of linear continuity (i.e., proportion of gaps) and habitat. Downes *et al.* (1997) found that in Australia, more native mammal species were found in corridors close to forest patches than corridors distant from patches. Also, arboreal mammals were more abundant in corridors than terrestrial mammals demonstrating that different species prefer corridors of different habitat types.

Prince Edward Island is located in the Gulf of St. Lawrence and encompasses an area of approximately 5660 km^2 (Weighs 1995). The landscape of Prince Edward Island is highly fragmented by agriculture with over 30% of the land devoted to agriculture. Hedgerows, small strips of vegetation bisecting farm fields, are often the only connections between isolated forest habitat and may be important in maintaining population connectivity for many small mammal species. Hedgerows have been found to be important habitat areas for small mammals and may sustain small mammal communities similar to those found in forest fragments (see Chapter 5). However, the relationship between hedgerow habitat characteristics and the use of hedgerows by small mammals is unknown.

The purpose of this study was to investigate the relationship between the use of hedgerows by small mammals and both internal and external characteristics of hedgerow structure. Internal structure focused on the microhabitat characteristics of hedgerows while external structure focused the form of hedgerows and their relationship with the surrounding agricultural fields and forest fragments. Previous surveys indicate that 16 species of small mammals are present on Prince Edward Island (Prescott 1980, Bateman and Prescott 1984, Silva 1999, Silva *et al.* 2000, Silva 2001). Eleven small mammal species have been found to occur in hedgerows on Prince Edward Island including two insectivores, eight rodents, and one carnivore, with the eastern chipmunk (*Tamias striatus*) being the most abundant and widespread species in hedgerows (see Chapter 5). It is expected that for mobile habitat generalists, such as the eastern chipmunk and American red squirrel (*Tamiasciurus hudsonicus*), external features of the hedgerow will be more important in determining hedgerow use. However, less mobile species, such as the deer mouse (*Peromyscus maniculatus*) and southern red-backed vole (*Clethrionomys gapperi*), are expected to be more influenced by internal hedgerow characteristics.

6.2 Methods

This study was conducted in three sites located in central Prince Edward Island. A total of 13 hedgerows and 12 forest fragments were studied. All study sites (Prince Edward Island National Park, Macphail Wood, Pleasant Grove) shared three characteristics: 1) forest fragments of similar cover type, 2) low intensity agriculture surrounding the fragments, and 3) a network of at least three hedgerows that varied in length (70 m to 720 m) and width (9.18 m to 30.88 m) (Table 6.1). For the forest fragments, cover type was estimated using 1990 forestry inventory data (Prince Edward Island Department of Agriculture and Forestry) coupled with Geographic Information Systems (MapInfo:GIS). All forest fragments were composed of 30% red maple (*Acer rubrum*), 20% white birch (*Betula papyrifera*), 20% balsam fir (*Abies balsamea*), 20% white spruce (*Picea glauca*), and 10% poplar (*Populus sp.*). The average canopy height in forest fragments was 14 m. Forest inventory data was not available for hedgerows, however, canopy composition of hedgerows ranged from predominantly white spruce (*Picea glauca*) to a mixed-wood type containing white spruce, white birch, red maple, and poplar. All hedgerows selected for this study contained a mature white spruce backbone characteristic of hedgerows found on Prince Edward Island (Pharoah 1983). Understory vegetation was highly variable and included shrubs (*e.g.*, *Rubus idaeus*, *Crataegus sp.*, *Rosa virginiana*, *Kalmia angustifolia*), grasses, herbs (*e.g.*, *Cornus canidensis*, *Aralia nudicaulis*, *Vaccinium angustifolium*), and bare ground. Hedgerow vegetation that occurred along fencelines between fields provided additional habitat and formed corridor networks between forest fragments. The surrounding farm fields were used primarily for hay and barley production. However, two fields at the Macphail site were also used for potato production.

Table 6.1. Hedgerow structural characteristics examined during this study.

Site[a]	Hedgerow	Length (m)	Width ± SD[b] (1 m height)	Width ± SD[b] (2 m height)	Connectivity[c]	Understory (H')[d]	Overstory (H')[d]
1	HA	250	12.88 ± 1.57	10.81 ± 3.38	2	2.19	2.41
	HB	130	13.71 ± 5.07	12.87 ± 6.09	2	2.30	2.35
	HC	490	13.58 ± 3.54	8.98 ± 5.20	3	2.74	2.11
2	HA	250	9.55 ± 1.71	9.18 ± 1.95	2	2.07	2.79
	HB	200	31.02 ± 7.30	30.88 ± 7.21	1	2.94	2.70
	HC	380	13.06 ± 4.16	12.81 ± 4.41	1	2.26	2.29
3	HA	720	12.74 ± 4.17	10.06 ± 4.54	2	2.01	2.37
	HB	140	15.38 ± 2.08	15.05 ± 2.57	1	3.35	2.30
	HC	130	16.23 ± 1.96	12.85 ± 5.96	1	2.55	1.93
	HD	70	14.32 ± 3.08	13.48 ± 1.12	2	2.37	2.22
4	HA	450	13.09 ± 4.03	10.74 ± 4.65	2	2.25	2.31
	HB	230	12.15 ± 1.71	11.37 ± 2.57	1	2.54	2.25
	HC	210	20.36 ± 8.98	17.85 ± 10.04	1	2.03	2.12

[a] Sites 1 and 4 refer to the Prince Edward Island National Park, Site 2 refers to the Macphail Woodlot, and Site 3 refers to the Pleasant Grove study site.

[b] SD = standard deviation.

[c] 1= connected on both ends, 2= connected on one end, 3= no connections

[d] $H' = -\sum (p_i)(\log_2 p_i)$, where p_i is the proportion of total samples belonging to the ith species (Shannon and Weiner 1949).

Trapping Procedures

Small mammals were trapped between May and September 2001. Each site was trapped monthly for three consecutive days with fragments and hedgerows sampled simultaneously. Large Sherman live-traps (50 x 62 x 165 mm) were baited with whole sunflower seeds and contained cotton bedding in the colder months. In the hedgerows, trap stations were placed at 10 m intervals throughout the length of the hedgerow, with one trap per station located mid-width in the hedgerow vegetation. In each habitat fragment, trap stations were placed at 20 m intervals in a grid configuration which was centered around the intersection of the hedgerow and fragment. Grid configurations were determined by the size and shape of the fragments. In some fragments the grid encompassed the entire fragment, while in others it sampled a portion of the fragment. However, the maximum area covered by a trapping grid was 6400 m^2 regardless of fragment size. Traps were checked twice daily, morning and evening. Captured animals were identified, ear tagged (using Monel fingerling tags), and body mass (g), body length (mm), tail length (mm), and hind foot length (mm) were recorded. Reproductive condition of each animal was noted and classified as non-reproductive, scrotal, or nipples present. Traps that were undisturbed or contained an animal were considered to be 100% effective, traps moved but not sprung were 50% effective, and traps sprung but not containing an animal were 0% effective.

Internal features

Several hedgerow habitat characteristics were measured at each trap location twice during the field season (early and late summer). Percent cover was estimated in 10% cover class intervals (0% to 100%) for trees (>4 m), tall shrubs (1.5-4 m), tall vines and creepers (1.5-4 m), shrubs (<1.5 m), vines and creepers (<1.5 m), grasses, herbs, litter/bare ground, and logs (*sensu* Bennett *et al.* 1994). Litter depth (cm) and soil moisture were also measured. Cover by grasses, herbs, and litter/bare ground was estimated using a 1 x 1-m square while cover by trees, shrubs, and vines was estimated using a densitometer. For each trap location, all vegetation, litter, and soil characteristics were measured at five fixed points along a transect line which spanned the width of the hedgerow. The five points were evenly distributed along this transect line to include two edge points (where the hedgerow vegetation intersected with surrounding matrix) and three interior points, with the trap location being the center-most point. Woody plants >2 m in height that were located within 5 m of the transect line were identified and grouped according to species. The habitat measurements from the two time periods were averaged to give values for each characteristic that represented the vegetation, litter, and soil characteristics at each transect point for the entire summer. Habitat characteristics at each transect point were averaged to give an overall value for each trap station. The habitat characteristics at the center-most point of the transect (the trap location) were also considered separately resulting in three values per habitat characteristic: average (AVG), standard deviation (SD), and center-most point (MID). A total of 33 variables were included in the analyses; 11 habitat characteristics with 3 values per characteristic.

The same habitat characteristics measured in hedgerows were also measured in each forest fragment. Each of the habitat variables was measured at each trap station and then averaged to give an overall value characterizing the forest composition. All trees within a 2 m radius of each trap station were identified and grouped according to species. The percentages of softwoods and hardwoods were calculated using GIS to give an overall picture of the canopy composition of each fragment.

External features

Preliminary estimates of hedgerow length (m) and width (m) were obtained from GIS. However, due to the ephemeral nature of hedgerows on Prince Edward Island, final measures of hedgerow length were approximated using the number of traps that were included in each hedgerow. Hedgerow width was measured every 20 m at 1 m and 2 m above ground (*sensu* Bennett *et al.* 1994). These measurements were averaged to give an overall width for each hedgerow. Hedgerow shape was determined by the ratio width-length (W/L). We determined the connectivity of hedgerows and forest fragments by counting the number of fragments to which the hedgerow was connected (1= connected on two ends, 2= connected on one end, 3= unconnected). Linear continuity was determined by the number and proportion of gaps present in each hedgerow. Gaps were lengths of hedgerow >5 m that lacked trees in the canopy (*sensu* Bennett *et al.* 1994). The length of each gap was measured, vegetation species identified, and gaps were categorized into two groups, 1) those with shrubs, grasses, or herbs in the understory, and 2) those that lacked ground cover (*e.g.*, farm roads). The proportion of gaps along each hedgerow as well as the proportion of gaps in each category was calculated (total length of gaps / length of hedgerow).

Structural characteristics of forest fragments included fragment area (km^2), perimeter (km), and area-perimeter (A/P, km^2/km) ratio (Table 6.2). Spatial characteristics of forest fragments were determined after initial fragment selection using the Geographic Information System (GIS:ArcView, Environmental Systems Research Institute, 2000). Forest fragment outlines were provided by the P.E.I. Department of Agriculture and Forestry. Fragment size was calculated using polygon areas in the GIS database.

In order to determine the effect of the surrounding landscape on small mammal communities in hedgerows, several variables were measured using GIS:ArcView. The areas of surrounding agricultural fields were determined from polygon areas in the GIS database. The ratios hedgerow area-fragment

Table 6.2. Forest fragment structural characteristics examined during this study.

Site[a]	Fragment[b]	Area (km^2)	% Area sampled	Perimeter (km)	Area/Perimeter r(km^2/km)
1	F5	0.052	12.3	1.125	0.050
2	F1	0.018	31.0	0.595	0.030
	F2	0.014	46.0	0.507	0.028
	F3	0.015	29.0	0.564	0.027
	F4	0.035	18.0	1.202	0.029
	F5	0.023	28.0	0.671	0.034
3	F1	0.013	37.0	0.466	0.028
	F2	0.006	80.0	0.299	0.020
	F3	0.012	53.0	0.435	0.027
4	F1	0.010	48.0	0.704	0.014
	F4	0.065	10.0	1.720	0.038
	F12	0.560	0.6	1.505	0.037
	F13	0.058	6.2	1.181	0.049

[a] Sites 1 and 4 are within the Prince Edward Island National Park, Site 2 is Macphail Woods, and Site 3 is Pleasant Grove.

[b] See pages 48, 51, 55 for maps of study sites and identification of forest fragments.

area (AH/AF) and hedgerow area-field area (AH/Afield) were calculated. They represented the relationship between hedgerows and the surrounding landscape. Hedgerow area/field area was an indicator of forest fragment isolation, with increased field size reflecting increased fragment isolation.

Analyses

To standardize for differences in trapping effort, relative abundance (P_R) was calculated as total population size (P_T) divided by trapping effort and multiplied by 100: $P_R = [(P_T / \mathrm{TNT}) \times 100]$, where TNT is the total number of trap nights (Silva 2001). Species richness was calculated for each hedgerow and forest fragment by counting the different species found to occur in these areas. Percent trapping success was calculated for all morning trapping sessions, all evening trapping sessions, and the entire field season (morning and evening combined). The Shannon-Weiner index of diversity, $H' = \sum (p_i)(\log_2 p_i)$ where p_i is the proportion of individuals belonging to the ith species (Shannon and Wiener 1949), was calculated for each hedgerow using the software package Ecological Methodology (Krebs 2000).

All data were tested for normality using the Kolmogorov-Smirnov goodness of fit test. The Pearson correlation analysis was used to examined relationships between small mammal community variables (i.e., species richness, species diversity, abundance of small mammals) and internal and external hedgerow habitat variables. Principle component analysis (PCA) was performed on correlation matrices to reduce the number of hedgerow habitat characteristics. The new variables (factors) are linear combinations of the original variables (Williams 1993). PCA factors with eigenvalues >1 were retained and factor loadings with magnitudes greater than 0.5 were considered biologically significant (Dillon and Goldstein 1984). Factors with the highest loadings were used to interpret each component. Relationships between PCA factors and small mammal community variables were determined using stepwise multiple regression analyses. Relationships between forest fragment habitat characteristics and small mammal community variables were also examined using Pearson correlation and stepwise multiple regression analyses.

6.3 Results

Small mammal captures

A total of 751 small mammals were captured during 8502 trap nights. In hedgerows, 221 different individuals representing 11 species were captured, while in forest fragments 246 individuals representing 10 species were captured. Two hedgerows contained 8 species, while two forest fragments only contained 6 species (Figures 6.1 and 6.2).

The eastern chipmunk was the most abundant and widespread species (Figures 6.1 and 6.2). Eastern chipmunks constituted 68% of the total captures

Figure 6.1. Total captures per species in hedgerows (H) at each study site (S1, S2, S3, S4).

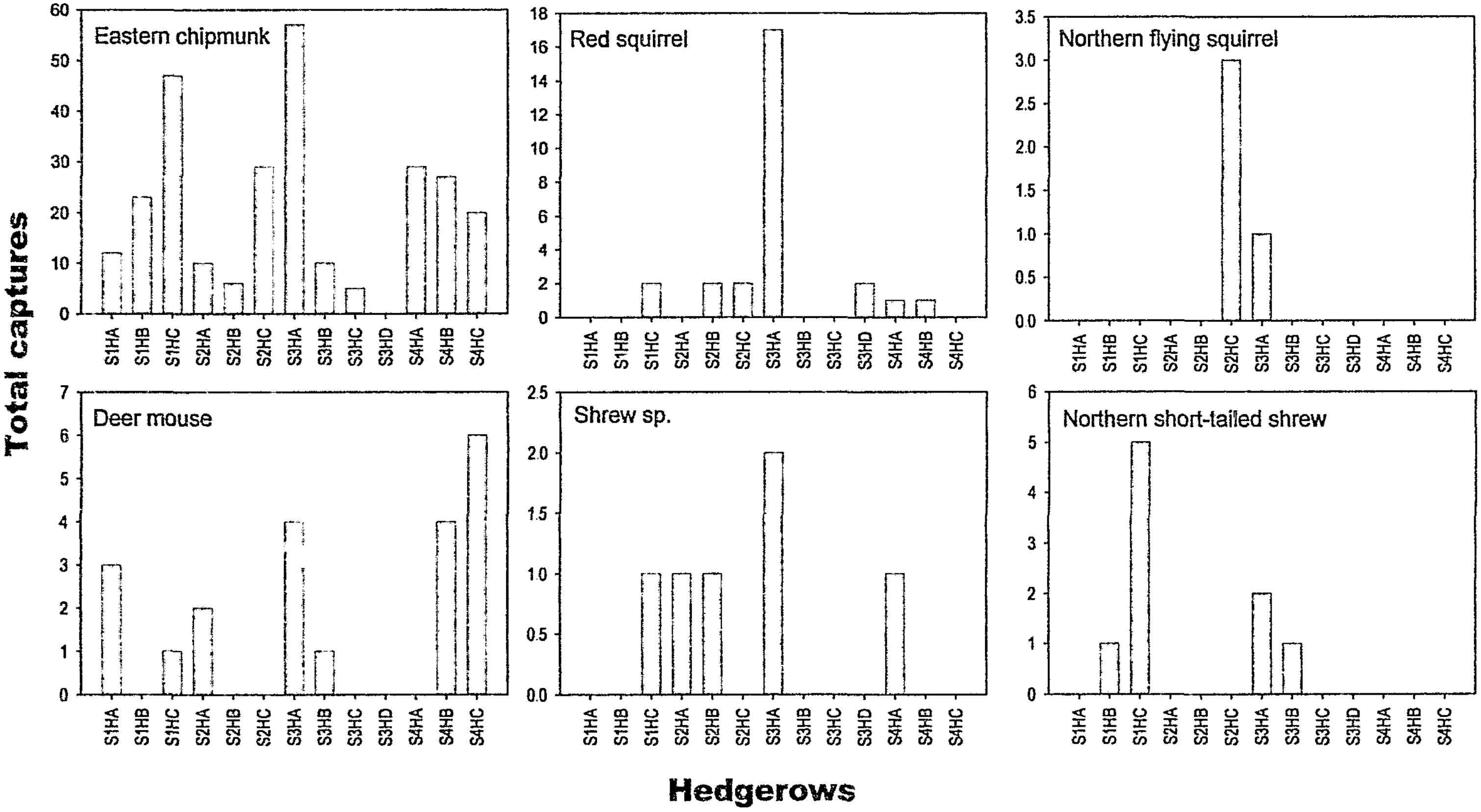


Figure 6.1. Continued from page 106.

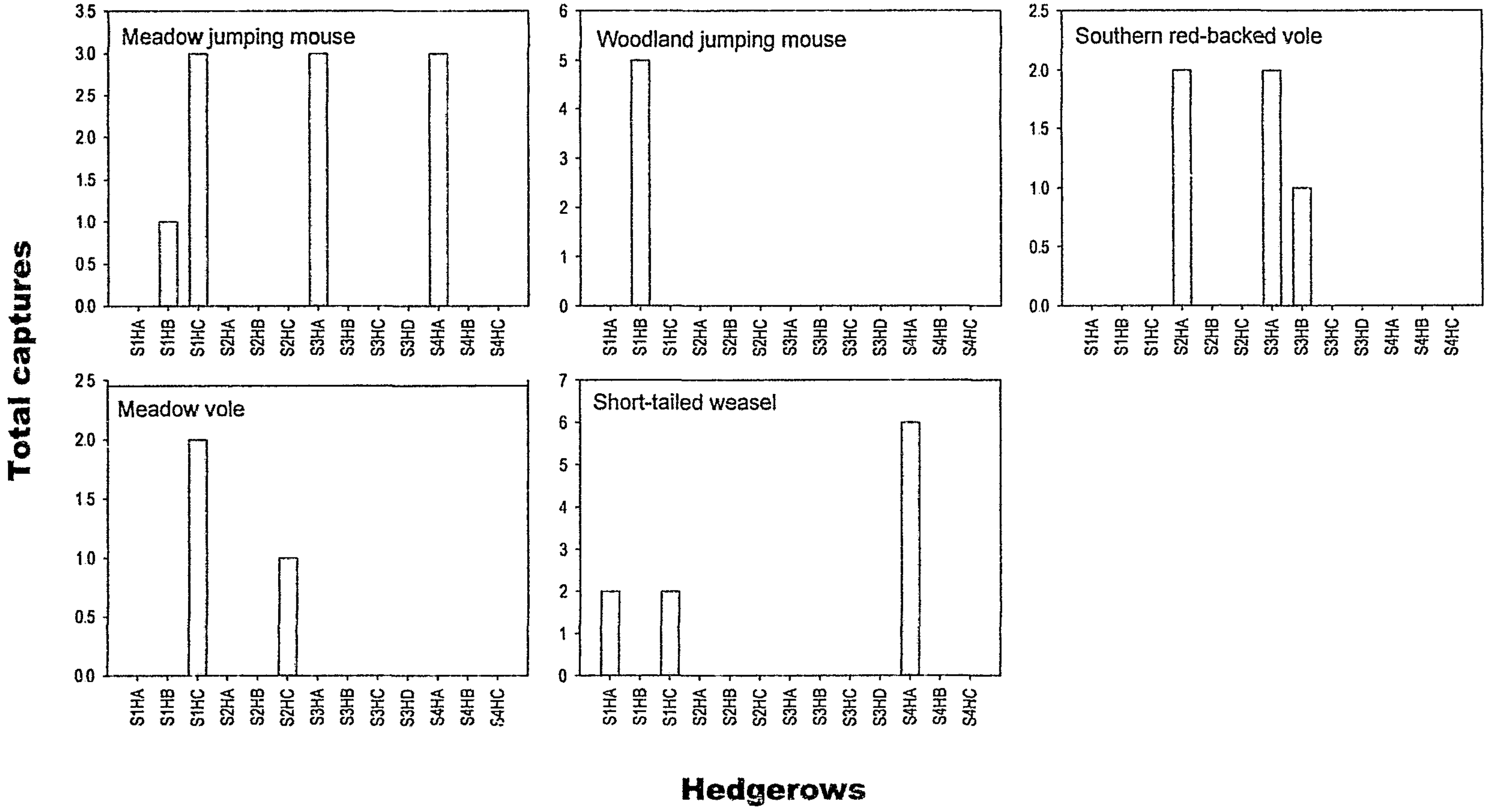
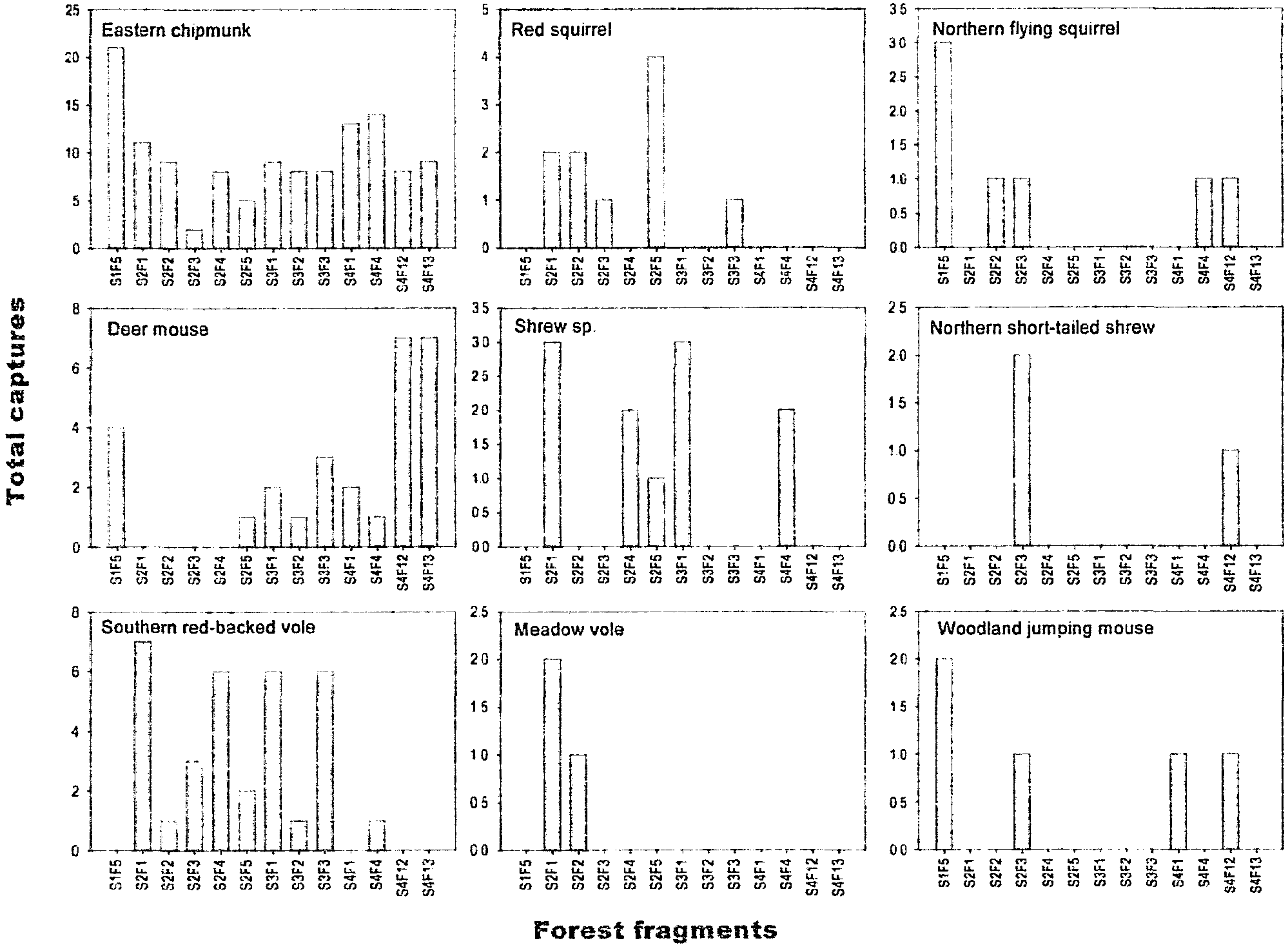


Figure 6.2. Total captures per species in forest fragments (F) at each study site (S1, S2, S3, S4).



and occurred in all forest fragments as well as 12 hedgerows. The meadow jumping mouse (*Zapus hudsonius*) was only captured in hedgerow habitat. The southern red-backed vole, deer mouse, and northern flying squirrel (*Glaucomys sabrinus*) were more abundant in forest fragments and occurred in more fragments than hedgerows (Figures 6.1 and 6.2). One possible explanation for this is that hedgerows may not provide as much habitat for these species.

Small mammal habitat associations within hedgerows

Principle component analyses of the hedgerow habitat characteristics yielded 5 factors that cumulatively explained 75.86% of the variation in small mammal community characteristics. Based on the dominant factor loadings and biological interactions between factors, we interpreted the hedgerow characteristics as vegetation, internal hedgerow structure, length, linear continuity, and soil/ground cover (Table 6.3). Percent of grass (PGRS) loaded highly on factor 1, and percent canopy (PTREESD) and litter depth (PLITMID) loaded highly but negatively on the same factor. This factor was interpreted as vegetation. Three variables, connectivity (NCONNECT), width at 2m height (WIDTH2M), and percent of herbs (PHRBAVG), loaded strongly on factor 2. Hedgerow width may have positively influenced the percent of herbs in hedgerows by providing greater canopy cover which reduces the amount of sunlight, wind, and other negative effects resulting from the close proximity to the surrounding fields. Due to the relationship between width and percent of

Table 6.3. Results of a principle components analysis on vegetative characteristics recorded in hedgerows.[a]

Variable	Prin1	Prin2	Prin3	Prin4	Prin5
Eigenvalues	10.541	8.109	6.979	5.874	4.152
% variance	22.428	17.252	14.849	12.498	8.835
NCONNECT	0.520	**-0.730**	0.104	0.003	0.166
LENGTH	0.493	-0.100	**0.671**	0.126	0.406
WIDTH2M	0.041	**0.685**	-0.587	0.212	0.247
W/L	-0.452	0.067	**-0.854**	0.072	0.146
AH/Afield	0.373	0.509	0.156	0.243	**0.567**
PROPGAPS	0.047	-0.335	0.207	**0.747**	-0.327
PTREESD	**-0.841**	0.166	-0.033	0.166	0.114
PTSHBMID	0.391	-0.097	-0.317	**-0.666**	0.266
PVAVG	0.048	0.056	0.480	**0.670**	-0.284
PGRSAVG	**0.758**	0.360	-0.448	0.058	-0.167
PHRBAVG	-0.196	**-0.811**	-0.232	-0.146	-0.110
PLITMID	**-0.886**	-0.032	-0.014	0.340	-0.144
PLOGMID	0.047	0.497	**0.659**	-0.417	-0.057
LDEPMID	0.353	0.092	-0.019	0.210	**0.663**
SOILAVG	0.315	0.459	-0.109	-0.410	**-0.622**

[a] Presented are the eigenvalues and eigenvectors for the first five principle component axes. Loadings for variables used to characterize each axis are emphasized with bold type and variables that did not characterize an axis are omitted.

herbs, this factor was characterized by width and connectivity and interpreted as internal hedgerow structure. Hedgerow length (LENGTH) and percent of logs (PLOGMID) loaded highly on factor 3, and width-length (W/L) loaded highly but negatively on the same factor. Hedgerow length greatly influenced W/L due to greater variation in hedgerow length ($\bar{x}$= 278 ± 192.5 m) than hedgerow width ($\bar{x}$= 14.4 ± 5.5 m). Percent of logs was influenced by both length and width. Long, narrow hedgerows contained more logs as a result of windfall and landowners cutting trees that encroach on the surrounding fields. Due to the relationship between the percent of logs and hedgerow length, factor 3 was interpreted as length. The proportion of gaps (PROPGAPS) and percent of vines (PVAVG) loaded highly on factor 4, and percent of tall shrubs (PTSHBMID) loaded highly but negatively on this factor. Few tall shrubs were present in hedgerow gaps reducing the overall percent of tall shrubs in hedgerows with a high proportion of gaps. However, the percent of vines was positively related to the proportion of gaps with gaps containing the majority of vines present in hedgerows. Due to the relationships between these vegetation variables and the proportion of gaps, this variable was interpreted as linear continuity. Litter depth (LDEPMID) loaded highly on factor 5 and soil moisture (SOILAVG) loaded highly but negatively on factor 5. This factor was interpreted as soil/ground cover.

There was considerable discrepancy between the abundance of eastern chipmunks and the abundance of all other species trapped in hedgerows and forest fragments. Therefore, we analyzed the abundance of eastern chipmunks separately from the abundance of other small mammal species. Fifteen hedgerow habitat characteristics as well as the five PCA factors (Table 6.3) were included in multiple regression analyses. Species richness ($r^2=0.789$, $p=0.001$, $n=13$), total abundance ($r^2=0.856$, $p=0.001$, $n=13$), abundance of chipmunks ($r^2=0.795$, $p=0.001$, $n=13$), and abundance of other species ($r^2=0.841$, $p=0.001$, $n=13$) was best explained by hedgerow length. When hedgerow length was excluded from the analyses, 94% ($p=0.001$, $n=13$) of the variation in species richness was explained by litter depth, percent logs, and hedgerow area/area field. Furthermore, 77.6% ($p=0.001$, $n=13$) of the variation in the abundance of other species was explained by shape and PCA factor 5, soil/ground cover.

Despite low abundances of other species, relationships between the total abundance of each species and hedgerow habitat characteristics was investigated. The abundance of northern short-tailed shrews (*Blarina brevicauda*) was positively associated with the proportion of gaps ($r=0.639$, $p=0.019$, $n=4$). The abundance of American red squirrels was positively correlated with hedgerow length ($r=0.760$, $p=0.003$, $n=7$) and AH/Afield ($r=0.659$, $p=0.014$, $n=7$). Approximately 61% of American red squirrels were captured in the longest hedgerow. The deer mouse, northern flying squirrel, southern red-backed vole, and meadow jumping mouse were not significantly associated with any habitat variables ($p>0.05$). However, abundance of the short-tailed weasel (*Mustela erminea*) was negatively correlated with canopy cover ($r= -0.608$, $p=0.028$, $n=3$).

Small mammal habitat associations within forest fragments

In forest fragments, species richness was not significantly associated with any structural or habitat variables. However, relative abundance of small mammals was positively correlated with fragment area ($r=0.590$, $p=0.034$, $n=13$), perimeter ($r=0.585$, $p=0.036$, $n=13$), and area/perimeter ($r=0.572$, $p=0.041$, $n=13$). The abundance of eastern chipmunks was not associated with any habitat variables. Stepwise multiple regression analyses showed that 91% ($p=0.001$, $n=13$) of the variation in the abundance of other species was explained by area/perimeter, percent grass, and fragment area.

6.4 Discussion

The landscape of Prince Edward Island is severely fragmented by agriculture with few areas of continuous forest remaining. In landscapes such as this, corridors have been proposed as a management tool to alleviate the effects of isolation on wildlife. Hedgerows have had a long standing influence on Prince Edward Island's landscape and may act as corridors as well as extended habitat for many small mammal species. Overall, our results show that hedgerows may sustain small mammal communities similar to those found in forest fragments. Species richness in hedgerows was slightly higher than in forest fragments, suggesting that as well as providing habitat for woodland species, hedgerows may provide habitat for species found in the surrounding agricultural landscape. Previous studies have found that species such as the meadow vole (*Microtus pennsylvanicus*) and meadow jumping mouse occur in hedgerows characterized by low canopy cover (Barnes and Linder 1982, Yahner 1982, Yahner 1983). Meadow voles were captured in low abundance in both forest fragments and hedgerows, suggesting that this species may be transient in both habitats. Silva (2001) also found that meadow voles were not abundant within forest fragments. Meadow jumping mice were only captured in hedgerow habitat. Most individuals were captured in areas characterized by low canopy cover and shrubby habitat. However, three individuals were captured in an area with high canopy cover shortly after the surrounding hay fields were harvested, suggesting that hedgerows with high canopy cover may be used by this species as extended habitat during crop harvest.

The eastern chipmunk was the most abundant and widespread species, captured in both hedgerows and forest fragments. However, our results contradict prior studies which indicate that eastern chipmunks may not reach high abundances on Prince Edward Island (Bateman and Prescott 1984). The high abundances of eastern chipmunks within hedgerows suggests that hedgerows may be particularly important for maintaining eastern chipmunk populations within agricultural landscapes. Previous studies have indicated that hedgerows may be important to eastern chipmunks acting as corridors, breeding habitat, and extended habitat (Henderson *et al.* 1985, Bennett *et al.* 1994, Henein *et al.* 1998). The abundance of eastern chipmunks was associated with hedgerow length but not with any hedgerow habitat characteristics. Previous studies have indicated that eastern chipmunks are nearly ubiquitous with respect to habitat characteristics (Nupp and Swihart 2000) and within the Prince Edward Island National Park, eastern chipmunks were captured in nearly all of the wooded habitats (Silva *et al.* 2000). Therefore, structural variables such as hedgerow length may be most important in determining the use of hedgerows by eastern chipmunks.

Species richness and the abundance of other small mammal species was also positively associated with hedgerow length, even when the longest hedgerow was removed from the analysis. One explanation for this is that long hedgerows (>400 m) may provide a variety of habitats emulating the habitat variation found in forest fragments. Since the number of traps present in hedgerows was proportional to hedgerow length, it is not expected that high species richness in long hedgerows was a result of oversampling. Hedgerow width and hedgerow shape were not significantly correlated with any of the small mammal community variables. One explanation for our findings is that within this study there was not sufficient variation in hedgerow width. Average width varied from approximately 10 m to 20 m, with only one hedgerow wider than 20 m. Due to the lack of variation in hedgerow width, all hedgerows were characterized as long and narrow.

When hedgerow length was excluded from the analysis, species richness was associated with the percent of logs, litter depth, and the ratio hedgerow area-area of the surrounding fields. Yahner (1983) also found that small mammal species richness in hedgerows was positively associated with hedgerow size and microhabitat complexity. However, the relationship between adjacent forest fragments and the surrounding landscape may have influenced species richness in hedgerows. In Sites 2 and 3, several forest fragments were in close proximity to large forested areas with the only separation from these areas being small farm roads, small streams, or clearcuts. The surrounding forested areas may have acted as sources contributing to a higher small mammal species richness within these forest fragments. This may have resulted in higher species richness within connecting hedgerows. There was a positive relationship between species richness within hedgerows and the ratio hedgerow area-field area, suggesting that hedgerows embedded in large fields and connected to more isolated forest fragments contain a lower species richness than hedgerows in small fields and connected to less isolated forest fragments.

Species richness in forest fragments was not associated with any habitat characteristics. One explanation for this difference may be that there was more variation in microhabitat complexity among hedgerows than forest fragments. For example, variation in the percent of logs was greater among hedgerows than among forest fragments. Previous studies have found that the abundance of several small mammal species such as the southern red-backed vole, northern short-tailed shrew, and common shrew (*Sorex cinereus*) was positively associated with the presence of logs and other woody debris (Gunderson 1959, Geier and Best 1980, Yahner 1983). Therefore, it is likely that characteristics of microhabitat complexity such as the percent of logs, are important for small mammal species in both hedgerows and forest fragments. Greater variation in microhabitat characteristics of forest fragments may be necessary to determine specific habitat requirements of small mammal species occurring in forest fragments.

Several other species were associated with hedgerow habitat characteristics. The abundance of northern short-tailed shrews was positively associated with the proportion of gaps. These animals were often captured in gaps dominated by grasses and low shrubs. Previous studies indicate that northern short-tailed shrews are habitat generalists occurring in many different habitat types (Manson *et al.* 1999). However, Yahner (1983) also found that within hedgerows this species preferred shrubby habitat.

The American red squirrel was positively associated with hedgerow length, with the longest hedgerow containing 61% of all captures. However, observational evidence suggests that the actual relationship between American red squirrel abundance and hedgerow length is unclear. The longest hedgerow, Site 3-HA, was separated from a forest fragment by a 3 m wide dirt road and several red squirrels were observed crossing the road and moving between habitats. The high abundance of American red squirrels in this hedgerow could have been a result of red squirrels from the adjacent fragment using the hedgerow as an additional foraging area. Previous studies have found that Eurasian red squirrels (*Sciurus vulgaris*) used hedgerows as extended foraging areas (Wauters *et al.* 1994). Several American red squirrels were observed in hedgerows where red squirrels were not captured. The use of traps on trees may have provided a more robust estimate of the abundance of this arboreal species.

The northern flying squirrel, deer mouse, and southern red-backed vole were more abundant and widespread in forest fragments than hedgerows. Previous studies have found that northern flying squirrels generally prefer mature forests (*e.g.*, Witt 1992). This type of habitat was limited among hedgerows and forest fragments. However, 3 of the 4 individuals found in hedgerow habitat were captured in Site 2-HC which contained many large trees, suggesting that hedgerows with large trees may be beneficial to this species. The deer mouse is considered a generalist species (Pasitschniak-Arts and Messier 1998) and was the second most abundant and widespread species within the Prince Edward Island National Park (Silva *et al.* 2000). The abundance of deer mice was not significantly associated with any hedgerow habitat characteristics, supporting the idea that it is a generalist species. The deer mouse was more abundant and widespread in forest fragments than hedgerows. One explanation may be that mice in hedgerows may experience higher mortality rates from predation than those in fragments. A previous study on white-footed mice (*Peromyscus leucopus*) found that the survival of litters born in edge and hedgerow habitat was much less than litters born in forest habitat (Morris and Davidson 2000). Southern red-backed voles were also more widespread and abundant in forest fragments than hedgerows. The abundance of southern red-backed voles was not associated with any hedgerow habitat characteristics. However, it was observed that southern red-backed voles were most abundant in forest fragments with a large abundance of stumps and logs. None of the hedgerows studied contained an abundance of stumps and logs, which may explain why red-backed voles were not abundant there.

Our findings show that hedgerows are an important habitat resource for small mammals, especially eastern chipmunks, occurring in highly fragmented landscapes of Prince Edward Island. Our results demonstrate that hedgerows provide habitat for many woodland species and may also be used by species in the surrounding landscape as refugia during crop harvest. Long hedgerows supported the greatest number of small mammal species suggesting that long hedgerows may be particularly important in small mammal conservation. Long, narrow hedgerows are also beneficial to landowners providing protection to crops. Management of long hedgerows that includes increasing microhabitat complexity may increase the value of hedgerows for conservation. Further investigation into movement patterns of eastern chipmunks in hedgerows is needed to determine whether hedgerows are used as movement corridors or as extended habitat.

7. THE ROLE OF HEDGEROWS IN AN AGRICULTURAL LANDSCAPE: MOVEMENT CORRIDORS OR EXTENDED HABITAT FOR EASTERN CHIPMUNKS (*TAMIAS STRIATUS*).

7.1 Introduction

Agricultural landscapes isolate populations of woodland species in habitat patches (Henderson *et al.* 1985) by destroying natural habitat patches and introducing matrix habitat (i.e., crops) into the landscape. Increasing habitat fragmentation and recognizing the importance of dispersal and movement between fragments has led to the consideration of corridors as a management tool (Stewart and Hutchings 1996). However, even though numerous studies have examined corridors, their importance to isolated populations of organisms is still unknown. Corridors may enhance the viability of populations by leading species across an inhospitable landscape toward isolated habitat remnants and have the potential to facilitate the movement of individuals from various sources (Tischendorf and Wissel 1997). Hedgerows or small strips of vegetation embedded in agricultural fields, form extensive networks in agricultural landscapes acting as corridors (Tischendorf and Wissel 1997). Although the primary functions of hedgerows do not focus on their usefulness to wildlife, hedgerows may provide benefits to wildlife living in agricultural landscapes. Linear patches such as hedgerows, can be used as movement pathways and as habitat for individuals living in linear patches (Rosenberg *et al.* 1997).

Hedgerows with distinct boundaries can serve as extended habitats by providing for an organism's daily requirements, such as foraging and shelter (Tischendorf and Wissel 1997). Movement and habitat functions of linear patches are not exclusive, but in order to determine the value of linear patches to conservation it is important to determine which function is primary (Rosenberg *et al.* 1997).

There are two distinct types of habitat corridors based on function: those that facilitate movement but are not acceptable living habitat, and those that serve as living habitat, as well as being used for movement across the landscape (Bennett *et al.* 1994). External (*e.g.*, length, connectivity, linear continuity) and internal features (*e.g.*, width and species composition) of corridors may affect their function in the landscape. External features of corridors describe the form of the corridor and its relationship with adjacent patches, while internal characteristics determine corridor function (Forman 1991). Danielson and Hubbard (2000) found that wide corridors (*e.g.*, 32 m) may be used by oldfield mice (*Peromyscus polionotus*) as additional habitat rather than dispersal corridors. Ruefenacht and Knight (1995) found that tree density in corridors and gaps (i.e., 10 m wide areas lacking all vegetation ≤ 7 cm diameter breast high) was positively associated with the total number of crossings of gaps by deer mice (*Peromyscus maniculatus*) as well as the amount of corridor movement. In Ontario (Canada) Bennett *et al.* (1994) found that the abundance of resident eastern chipmunks (*Tamias striatus*) in corridors was best predicted by features of the habitat while the abundance of transients was best predicted by a combination of linear continuity and habitat. Downes *et al.* (1997) found that in Australia, more native mammal species were found in corridors close to forest patches than corridors distant from patches. Also, arboreal mammals were more abundant in corridors than terrestrial mammals suggesting that different species prefer corridors of different habitat types.

In this study, we examined the use of hedgerows in a farmland mosaic by the eastern chipmunk. The eastern chipmunk is a small, diurnal, burrow dwelling, sciurid mammal that occurs in all deciduous forest associations as well as in hardwood stands within the boreal forest (Snyder 1982). Eastern chipmunks also occur near buildings and houses making them an urban species as well as wilderness species (Snyder 1982). On Prince Edward Island, eastern chipmunks have been found to be both widespread and abundant within the Prince Edward Island National Park, occurring in all types of wooded habitat (*e.g.*, Acadian forest, mixed forest, hardwood forest, red pine plantation) (Silva *et al.* 2000, Silva 2001). Eastern chipmunks were also the most abundant species captured in hedgerows on Prince Edward Island (see Chapters 5 and 6). Several studies have shown that hedgerows may be particularly important for eastern chipmunks in agricultural landscapes. Henderson *et al.* (1985) found that hedgerows serve as movement corridors and habitat for small breeding populations of chipmunks. They concluded that wooded hedgerows are important for chipmunks and provide sufficient habitat connectivity to permit population continuity throughout the farmland mosaic. Henein *et al.* (1998) also found that hedgerows were important to eastern chipmunks and that the loss of these features or a reduction in their quality had detrimental effects on chipmunks' persistence, population size, and population variability. In order to better understand hedgerow use by eastern chipmunks on Prince Edward Island, patterns of hedgerow use as well as the distances that eastern chipmunks move in hedgerows were investigated and compared to the adjacent forest fragments. We also examined the importance of various physical and compositional hedgerow variables as factors determining hedgerow use by eastern chipmunks.

7.2 Methods

Study areas

This study was conducted in three sites located across central Prince Edward Island (Tables 7.1 and 7.2). Thirteen hedgerows and 12 forest fragments were studied. All study sites (Prince Edward Island National Park, Macphail Wood, Pleasant Grove) shared several characteristics: 1) forest fragments of similar cover type, 2) low intensity agriculture surrounding the fragments, and 3) a network of at least three hedgerows that varied in length (70 m to 720 m) and width (9 m to 30 m). Cover type of the forest fragments

Table 7.1. Structural characteristics of hedgerows examined during this study.

Site[a]	Hedgerow	Length (m)	Width ± SD[b] (1 m height)	Width ± SD[b] (2 m height)	Connectivity[c]	Understory (H')[d]	Overstory (H')[d]
1	HA	250	12.88 ± 1.57	10.81 ± 3.38	2	2.19	2.41
	HB	130	13.71 ± 5.07	12.87 ± 6.09	2	2.30	2.45
	HC	490	13.58 ± 3.54	8.98 ± 5.20	3	2.74	2.1[illegible]
2	HA	250	9.55 ± 1.71	9.18 ± 1.95	2	2.07	2.79
	HB	200	31.02 ± 7.30	30.88 ± 7.21	1	2.94	2.70
	HC	380	13.06 ± 4.16	12.81 ± 4.41	1	2.26	2.29
3	HA	720	12.74 ± 4.17	10.06 ± 4.54	2	2.01	2.37
	HB	140	15.38 ± 2.08	15.05 ± 2.57	1	3.35	2.30
	HC	130	16.23 ± 1.96	12.85 ± 5.96	1	2.55	1.93
	HD	70	14.32 ± 3.08	13.48 ± 1.12	2	2.37	2.22
4	HA	450	13.09 ± 4.03	10.74 ± 4.65	2	2.25	2.31
	HB	230	12.15 ± 1.71	11.37 ± 2.57	1	2.54	2.25
	HC	210	20.36 ± 8.98	17.85 ± 10.04	1	2.03	2.12

[a] Sites 1 and 4 refer to the Prince Edward Island National Park, Site 2 refers to the Macphail Woodlot, and Site 3 refers to the Pleasant Grove study site.

[b] SD= standard deviation

[c] 1= connected on both ends, 2= connected on one end, 3= no connections

[d] $H' = -\sum (p_i)(\log_2 p_i)$, where p_i is the proportion of total samples belonging to the ith species (Shannon and Weiner 1949).

Table 7.2. Structural characteristics of forest fragments examined during this study.

Site[a]	Fragment	Area (km^2)	% Area sampled	Perimeter (km)	area/perimeter (km^2/km)
1	F5	0.052	12.3	1.125	0.050
2	F1	0.018	31.0	0.595	0.030
	F2	0.014	46.0	0.507	0.028
	F3	0.015	29.0	0.564	0.027
	F4	0.035	18.0	1.202	0.029
	F5	0.023	28.0	0.671	0.034
3	F1	0.013	37.0	0.466	0.028
	F2	0.006	80.0	0.299	0.020
	F3	0.012	53.0	0.435	0.027
4	F1	0.010	48.0	0.704	0.014
	F4	0.065	10.0	1.720	0.038
	F12	0.560	0.6	1.505	0.037
	F13	0.058	6.2	1.181	0.049

[a] Sites 1 and 4 are within the Prince Edward Island National Park, Site 2 is Macphail Woods, and Site 3 is Pleasant Grove.

was estimated using 1990 forestry inventory data (Prince Edward Island Department of Agriculture and Forestry) coupled with Geographic Information Systems (MapInfo:GIS). According to 1990 forest inventory data, all forest fragments were composed of 30% red maple (*Acer rubrum*), 20% white birch (*Betula papyrifera*), 20% balsam fir (*Abies balsamia*), 20% white spruce (*Picea glauca*), and 10% poplar (*Populus sp.*), with a canopy height of 14 m. Forest inventory data was not available for hedgerows, however, canopy composition of hedgerows ranged from white spruce to a mixed-wood type containing white spruce, white birch, red maple, and poplar. All hedgerows selected for this study contained a mature white spruce backbone characteristic of hedgerows found on Prince Edward Island (Pharoah 1983). Understory vegetation was highly variable and included shrubs (*e.g.*, *Rubus idaeus*, *Crataegus sp.*, *Rosa virginiana*, *Kalmia angustifolia*), grasses, herbs (*e.g.*, *Cornus canidensis*, *Aralia nudicaulis*, *Vaccinium angustifolium*), and bare ground. Hedgerow vegetation that occurred along fencelines between fields provided additional habitat and formed corridor networks between forest fragments. The surrounding farm fields were used primarily for hay and barley. However, fields at the Macphail site were also used for potato production, a high intensity crop.

Trapping procedure

Eastern chipmunks were trapped between May and September 2001. Each site was trapped monthly for three consecutive days, for a total of 5 trapping periods. Large Sherman live-traps (50 x 62 x 165 mm) were baited with sunflower seeds and contained cotton bedding in the colder months. In the hedgerows, traps stations were placed at 10 m intervals throughout the length of the hedgerow, with one trap per station located mid-width in the hedgerow vegetation. In the adjacent forest fragments, traps were placed at 20 m intervals in one of four grid configurations centered around the intersection of the hedgerow and fragment. Grid configurations were determined by the area and shape of the fragments. In some areas the grid encompassed the entire fragment, while in others it sampled a portion of the fragment. However, the maximum area covered by a trapping grid was 6400 m^2 regardless of fragment area. Traps in both the hedgerows and fragments were checked twice daily, morning and evening. Since the eastern chipmunk is a diurnal species, it was expected that the majority of individuals captured would be recorded during the evening trap check. Captured animals were identified, ear tagged (Monel fingerling tags), and several standard body measurements were recorded. Reproductive condition of each animal was noted and classified as non-reproductive, scrotal, or nipples present. Females with nipples present and males with scrotal testes were considered reproductive adults. Juveniles and non-reproductive adults were categorized according to body mass (<80 g = juvenile, >80 g = non-reproductive adult) (*sensu* Bennett *et al.* 1994). Traps that were undisturbed or contained an animal were considered to be 100% effective, traps moved but not sprung were 50% effective, and traps sprung but not containing an animal were 0% effective. For the purpose of this study, traps that contained individuals of other species were also considered 0% effective.

Habitat characteristics

Preliminary estimates of length (m) and width (m) were obtained from GIS. However, due to the ephemeral nature of hedgerows on Prince Edward Island, final measures of hedgerow length was estimated using the number of traps placed in each hedgerow. Width was measured at 20 m intervals throughout the length of the hedgerow at 1 m and 2 m above the ground (*sensu* Bennett *et al.* 1994). These measurements were averaged to give an overall width at each height. The ratio width-length (W/L) provided an indicator of hedgerow shape. We determined the connectivity of hedgerows and forest fragments by counting the number of fragments to which the hedgerow was connected (1= connected on two ends, 2= connected on one end, 3= unconnected). Linear continuity was determined by the number and proportion of gaps present in each hedgerow. Gaps were lengths of hedgerow >5 m that lacked trees in the canopy (*sensu* Bennett *et al.* 1994). The length of each gap was measured, vegetation species identified, and gaps were categorized into two groups, 1) those with shrubs, grasses, or herbs in the understory, and 2) those that lacked ground cover (i.e., farm roads). The proportion of gaps along each hedgerow as well as the proportion of gaps in each category was calculated (total length of gaps / length of hedgerow).

Several habitat characteristics of hedgerows were measured at each trap twice during the field season (early and late summer). Percent cover was categorized into 10% cover class intervals (0% to 100%) for trees (>4 m), tall shrubs (1.5-4 m), tall vines and creepers (1.5-4 m), shrubs (<1.5 m), vines and creepers (<1.5 m), grasses, herbs, litter/bare ground, and logs (*sensu* Bennett *et al.* 1994). Percent canopy of trees, vines, and shrubs was estimated with a densitometer. Percent ground cover by grasses, herbs, and litter/bare ground was measured by imposing a 1 m^2 plot on the ground and estimating the percent of the ground which was not visible. Litter depth (cm) and soil moisture were also measured. All woody plants were identified to the species level and grouped based on height (>2 m and <2 m). At each trap location, vegetation, litter, and soil characteristics were measured at five fixed points along a transect line that spanned the width of the hedgerow. The five points were evenly distributed along this transect line to include two edge points (where the hedgerow vegetation intersected with surrounding matrix) and three interior points, with the trap location being the center-most point. Woody plants >2 m in height that were located within 5 m of the transect line were identified and grouped according to species. The habitat measurements from the two time periods were averaged to give values for each characteristic that represented the vegetation, litter, and soil characteristics at each transect point for the entire summer. Habitat characteristics at each transect point were averaged to give an overall value for each trap station. The habitat characteristics at the center-most point of the transect (the trap location) were also considered separately resulting in three values per habitat characteristic: average (AVG), standard deviation (SD), and center-most point (MID). A total of 33 variables were included in the analyses; 11 habitat characteristics with 3 values per characteristic.

Hedgerow use and distance moved

To determine habitat use, individuals were classified into 1) permanent resident, 2) temporary resident, and 3) transient, based on the number of times they were captured (*sensu* Bennett *et al.* 1994). Permanent resident animals included individuals captured in the same hedgerow or fragment during two or more trapping periods, temporary residents included individuals captured in a hedgerow or fragment during only one trapping period even if the individual was trapped several times during that period, and transients included animals captured in a hedgerow or fragment only one time throughout all trapping periods. The residency classification temporary residents was used to provide the greatest distinction between residents and transients. Temporary residents may include true residents that avoid traps or did not survive as well as individuals captured while moving through the landscape (Bennett *et al.* 1994). Within each of these categories, individuals were grouped according to reproductive condition and age.

The distances individuals moved within fragments and hedgerows were determined from capture data. While each animal's exact paths cannot be established using this method, capture data give a comprehensive representation of the distance each individual moved within the respective habitats. Distances were only calculated for individuals captured at least three times in the same habitat. Following Koeppl *et al.* (1977), we calculated the distance each individual traveled by determining the distance moved between successive capture locations ($d_i = [(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2]^{1/2}$), the mean sequential distance each individual traveled, ($l_k = (\sum d_i) / n-1$), and the weighted population home-range index. Sequential distance is the minimum distance the individual actually travels between captures. The weighted home-range index is based on the assumption that the reliability of the contribution of each individual to the population index varies directly with its sample size. These indices were used to compare the average distance individuals moved within each type of habitat. It was expected that individuals in hedgerows moved longer distances than those in forest fragments, suggesting that hedgerows may be used as movement corridors.

Analyses

To standardize for trapping effort, relative abundance (P_R) was calculated as total population size (P_T) divided by trapping effort and multiplied by 100: $P_R = [(P_T / TNT) \times 100]$, where TNT is the total number of trap nights (Silva 2001). All data were tested for normality using the Kolmogorov-Smirnov goodness of fit test. The overall average body mass (g) of eastern chipmunks was compared between hedgerow and fragment habitats using two-sample t-tests. T-tests were also used to compare the average body mass (g) of males and average mass (g) of females between habitats. Residency status (i.e., permanent resident, temporary resident, transient) was compared between hedgerow and fragment habitats using two-way ANOVA. Each of the three measures of distance traveled were also compared between fragment and hedgerow habitats using two sample t-tests.

The Pearson correlation analysis was used to examined relationships between eastern chipmunk residency classes (i.e., permanent resident, temporary resident, transient) and internal and external hedgerow habitat variables. Principle component analysis (PCA) was performed on correlation matrices to reduce the number of hedgerow habitat characteristics. The new variables (factors) are linear combinations of the original variables (Williams 1993). PCA factors with eigenvalues >1 were retained and factor loadings with magnitudes greater than 0.5 were considered biologically significant (Dillon and Goldstein 1984). Factors with the highest loadings were used to interpret each component. Relationships between PCA factors and small mammal community variables were determined using stepwise multiple regression analyses. Relationships between forest fragment habitat characteristics and small mammal community variables were also examined using Pearson correlation and stepwise multiple regression analyses.

7.3 Results

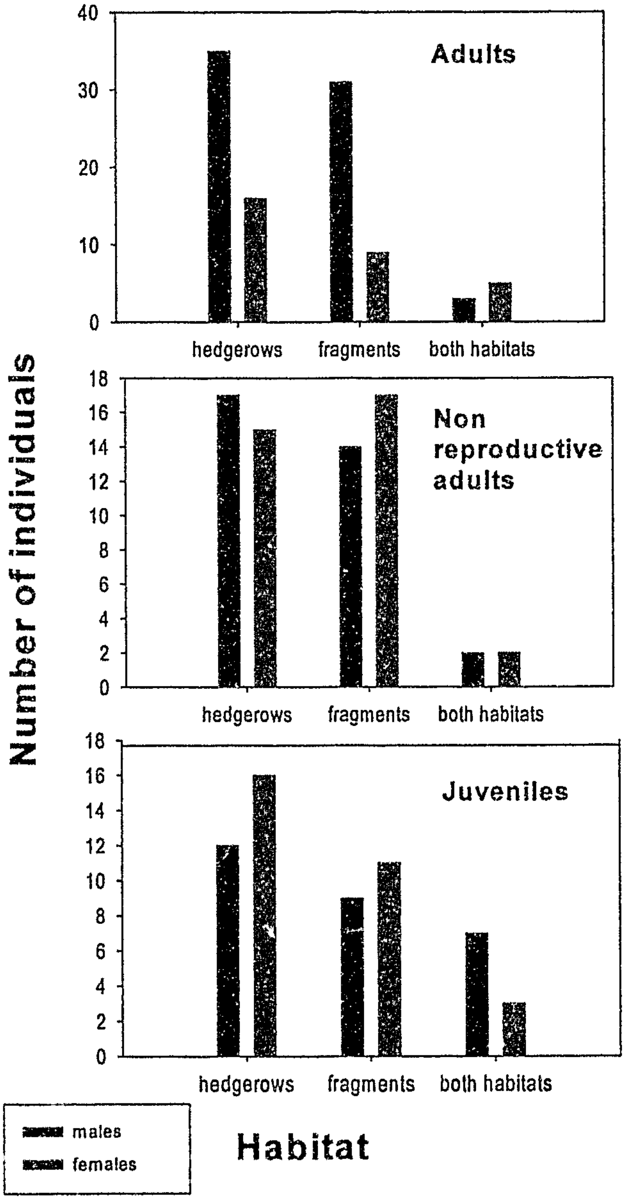
Abundance

A total of 260 captures representing 224 chipmunks (130 males, 94 females) were recorded in 5134 trap-days (Figure 7.1). Eastern chipmunks were captured in all forest fragments and 12 hedgerows. Only 10% of individuals were captured in both hedgerowand fragment habitat (Figure 7.1).

Hedgerow use

Eastern chipmunks of all age and sex classes were residents of hedgerows (Figure 7.1). Ninety-one percent of hedgerow residents were adults and non-reproductive adults. Individuals classified as non-reproductive adults were considered young of the year, most likely from the first breeding season in early April. Previous studies have indicated that two breeding seasons may occur on Prince Edward Island, the first in April and second in late July to early August (M. Silva, unpublished data). A similar age distribution occurred in fragments, with adults and non-reproductive adults composing 78% of residents. There was no significant difference between hedgerows and fragments with respect to the number of permanent resident females ($p>0.05$, $n=12$, two-sample t-test), the number of permanent resident reproductive females ($p>0.05$, $n=12$, two-

Figure 7.1. Number of eastern chipmunks in each age class. Note: adults= reproductive individuals, non-reproductive adults >80 g, juveniles <80 g.



sample t-test), and the number of juveniles (p<0.05, n=12, two-way ANOVA) in hedgerow and fragment habitat, suggesting that like fragments, hedgerows provide breeding habitat. Approximately 53% of reproductive females were captured in hedgerows and 48% of juveniles were captured in hedgerows exclusively, suggesting that breeding does occur within hedgerows.

Approximately 50% of individuals captured in both habitats were temporary residents, suggesting that these individuals may use both hedgerow and fragment habitat. Several chipmunks were residents of fragment habitat and temporary residents of hedgerow habitat (*e.g.*, Site 3, Female 2766 in Fragment 2 and Hedgerow B) indicating that hedgerows may also be used as additional foraging areas. Transients were the most abundant residency class in both hedgerows and forest fragments (Table 7.3). Hedgerows contained almost twice as many transient juveniles than fragments.

Hedgerow quality and distance moved

Principle component analyses of the hedgerow habitat characteristics yielded 5 factors that cumulatively explained 75.86% of the variation in small mammal community characteristics. Based on the dominant factor loadings and biological interactions between factors, we interpreted the hedgerow characteristics as vegetation, internal hedgerow structure, length, linear continuity, and soil/ground cover (Table 7.4). Percent of grass (PGRS) loaded

Table 7.3. Resident status for age and sex classes of chipmunks captured in hedgerows and forest fragments[a].

	Hedgerow			Forest Fragment		
	Resident	Temporary Resident	Transient	Resident	Temporary Resident	Transient
Adults						
Males	11	10	17	13	10	14
Females	7	9	6	5	5	6
Juveniles						
Males	1	9	11	5	5	5
Females	2	5	12	4	2	8
Non-reproductive adults						
Males	4	7	10	5	5	7
Females	10	8	3	6	5	8
Total	35	48	59	38	32	48

[a] Note that some individuals were transient or temporary residents in more than one location.

Table 7.4. Results of a principle components analysis on vegetative characteristics recorded in hedgerows.[a]

Variable	Prin1	Prin2	Prin3	Prin4	Prin5
Eigenvalues	10.541	8.109	6.979	5.874	4.152
% variance	22.428	17.252	14.849	12.498	8.835
NCONNECT	0.520	**-0.730**	0.104	0.003	0.166
LENGTH	0.493	-0.100	**0.671**	0.126	0.406
WIDTH2M	0.041	**0.685**	-0.587	0.212	0.247
W/L	-0.452	0.067	**-0.854**	0.072	0.146
AH/Afield	0.373	0.509	0.156	0.243	**0.567**
PROPGAPS	0.047	-0.335	0.207	**0.747**	-0.327
PTREESD	**-0.841**	0.166	-0.033	0.166	0.114
PTSHBMID	0.391	-0.097	-0.317	**-0.666**	0.266
PVAVG	0.048	0.056	0.480	**0.670**	-0.284
PGRSAVG	**0.758**	0.360	-0.448	0.058	-0.167
PHRBAVG	-0.196	**-0.811**	-0.232	-0.146	-0.110
PLITMID	**-0.886**	-0.032	-0.014	0.340	-0.144
PLOGMID	0.047	0.497	**0.659**	-0.417	-0.057
LDEPMID	0.353	0.092	-0.019	0.210	**0.663**
SOILAVG	0.315	0.459	-0.109	-0.410	**-0.622**

[a] Presented are the eigenvalues and eigenvectors for the first five principle component axes. Loadings for variables used to characterize each axis are emphasized with bold type and variables that did not characterize an axis are omitted.

highly on factor 1, and percent canopy (PTREESD) and litter depth (PLITMID) loaded highly but negatively on the same factor. This factor was interpreted as vegetation. Three variables, connectivity (NCONNECT), width at 2m height (WIDTH2M), and percent of herbs (PHRBAVG), loaded strongly on factor 2. Hedgerow width may have positively influenced the percent of herbs in hedgerows by providing greater canopy cover which reduces the amount of sunlight, wind, and other negative effects resulting from the close proximity to the surrounding fields. Due to the relationship between width and percent of herbs, this factor was characterized by width and connectivity and interpreted as internal hedgerow structure. Hedgerow length (LENGTH) and percent of logs (PLOGMID) loaded highly on factor 3, and width-length (W/L) loaded highly but negatively on the same factor. Hedgerow length greatly influenced W/L due to greater variation in hedgerow length ($\bar{x}$= 278 ± 192.5 m) than hedgerow width ($\bar{x}$= 14.4 ± 5.5 m). Percent of logs was influenced by both length and width. Long, narrow hedgerows contained more logs due to windfall and removal of trees encroaching on surrounding fields. Due to the relationship between the percent of logs and hedgerow length, factor 3 was interpreted as length. The proportion of gaps (PROPGAPS) and percent of vines (PVAVG) loaded highly on factor 4, and percent of tall shrubs (PTSHBMID) loaded highly but negatively on this factor. Few tall shrubs were present in hedgerow gaps reducing the overall percent of tall shrubs in hedgerows with a high proportion of gaps. However, the percent of vines was positively related to the proportion of gaps with gaps containing the majority of vines present in hedgerows. Due to the relationships between the vegetation variables and the proportion of gaps, this variable was interpreted as linear continuity. Litter depth (LDEPMID) loaded highly on factor 5 and soil moisture (SOILAVG) loaded highly but negatively on factor 5. This factor was interpreted as soil/ground cover.

The number of permanent residents was best predicted by hedgerow length (r^2= 0.712, p=0.001, n=12). However, when length was removed from the analyses, 51.2% (p=0.009, n=12) of the variation in the number of permanent residents was explained by W/L, suggesting that for permanent residents structural aspects of hedgerows may be important determinants of hedgerow quality. Variation in the number of temporary residents was best predicted by hedgerow length (r^2= 0.577, p=0.004, n=12). However, when length was removed from the analyses, 96.6 % (p=0.003, n=12) of the variation in the number of temporary residents was explained by AH/Afield, WIDTH2M, PLOG, and LDEP. The number of residents was positively correlated with connectivity (p=0.020, n=12). More residents were captured in less connected hedgerows than in well connected hedgerows, suggesting that well connected hedgerows may be used more as movement corridors than breeding or foraging habitat.

Two-sample t-tests indicated no significant difference in the mean sequential distance traveled by individuals (p>0.05, n=45), the longest distance traveled (p>0.05, n=45), or the mean population distance (p>0.05, n=24) between hedgerows and fragments. In fragments, the longest average distance moved was 90 m while in hedgerows the longest average distance moved was 170 m. However, only two adult males (out of 224 individuals) were captured in two different forest fragments.

7.4 Discussion

Hedgerows have had a long standing influence on the landscape of Prince Edward Island providing many benefits to landowners such as crop protection (Round Table Report 1997). Hedgerows may also benefit wildlife by providing additional habitat as well as acting as corridors through the agricultural landscape. However, our results show that hedgerows on Prince Edward Island are used more by eastern chipmunks as living habitat than movement corridors. Chipmunks were present in all fragments and most hedgerows. The majority of movement was intra-habitat movement. This was unexpected because several other studies conducted in Ontario (Canada) have indicated that hedgerows are important movement corridors for eastern chipmunks (Henderson *et al.* 1985, Bennett *et al.* 1994, Henein *et al.* 1998). One explanation for our findings is that chipmunk movements between habitats may be restricted by competition and predation risk. Individuals in fragments may not move into hedgerows due to an increased predation risk, while individuals in hedgerows may be restricted by competition within forest fragments. Previous studies within the Prince

Edward Island National Park showed that more short-tailed weasels were captured in hedgerows than forest fragments (*e.g.*, Silva 2001), suggesting that predation risk may be higher in hedgerow habitats.

Hedgerows may be important habitats on Prince Edward Island, providing both foraging and breeding habitat. Ten percent of individuals were captured in both hedgerow and fragment habitat, suggesting that hedgerows may be used as additional foraging areas. Many of these individuals were residents of fragments and generally stayed within 40 m of the fragment habitat, while some individuals traveled long distances into hedgerows before returning to the original fragment. One explanation for this is that foraging within hedgerows is most beneficial close to the fragment. Foraging efficiency in hedgerows has previously been found to be negatively associated with distance from the fragment (K. Duncan, unpublished data). As distance from the forest fragment increases, predation risk may outweigh benefits gained by foraging (Kieffer 1991, Kie 1999). Hedgerows may also provide breeding habitat since many reproductive females and juveniles were captured exclusively in hedgerow habitat, suggesting that breeding in hedgerows may occur independently of forest fragments. However, it should be noted that most juveniles captured in hedgerows were transients (i.e., only captured one time), suggesting that juveniles may experience higher mortality in hedgerows than fragments. However, more non-reproductive males were transients rather than permanent residents of hedgerows, suggesting that hedgerows may also be important dispersal pathways for chipmunks.

Hedgerow length was the most important factor determining the number of permanent residents. One explanation for this is that long hedgerows may contain a greater amount of suitable habitat than shorter hedgerows. However, the abundance of hedgerow permanent residents was not significantly associated with any habitat characteristics. This was unexpected considering that previous studies have found that several hedgerow vegetation characteristics (*e.g.*, % trees, shrubs, vines, grass, litter/bare ground) were important in determining the number of residents captured in hedgerows (Bennett *et al.* 1994). One explanation for this may be that since the hedgerows were first established approximately 65 years ago, this species may have had time to adapt to the habitat conditions within hedgerows, making those animals that are residents of hedgerows less habitat selective. Hedgerows also supported approximately the same number of permanent residents as forest fragments, suggesting that hedgerows are comparable to forest fragments with respect to the habitat requirements of the eastern chipmunks. However, this may have been due to increased trapping effort within hedgerows. There were approximately 5066 trap days in hedgerows compared to 3437 trap days in forest fragments. A greater number of traps within forest fragments may have resulted in more permanent residents recorded in forest fragments.

The number of hedgerow permanent residents was also positively associated with the level of hedgerow connectivity, with hedgerows connected to one fragment containing more permanent residents than hedgerows connecting two fragments. One explanation is that hedgerows connecting forest fragments are used more as movement pathways and less as extended foraging habitat. However, crops surrounding less-connected hedgerows may also act as a "fence" restricting movement to surrounding fragments, resulting in higher abundances in less connected hedgerows (i.e., the fence effect). Previous studies have indicated that high abundances of American red squirrels and flying squirrels in isolated forest fragments may have been due to the reduced ability of these species to disperse across the agricultural matrix and not the quality of habitat within the fragments (Bayne and Hobson 1998, Bayne and Hobson 2000; Nupp and Swihart 2000).

In order for hedgerows to be considered successful as corridors, chipmunks must move within them and use them to move between forest fragments. While there was no significant difference between the distances individuals traveled in hedgerows and forest fragments, more individuals moved longer distances in hedgerows than forest fragments. However, only two individuals were recorded in two forest fragments connected by hedgerows. While it is possible that these individuals could have also moved through the adjacent agricultural fields, previous studies have shown that eastern chipmunks seldom move through grassy fields or crops (Wegner and Merriam 1979, Merriam 1984, Bennett 1994, Silva 1999). It is possible that many other individuals also traveled between fragments moving undetected from one fragment to another. In an agricultural landscape in Ontario (Canada) Bennett *et al.* (1994) recorded several individuals using hedgerows to move between fragments. The trapping design in forest fragments may have reduced the number of individuals detected moving between fragments. Hedgerows were sampled more heavily than fragments and due to the linear shape of hedgerows, it was more likely that animals would encounter traps in hedgerows than fragments. In future studies, a higher concentration of traps around the intersection of fragments and hedgerows may allow greater detection of inter-habitat movement. Also, this study was only conducted over one field season which may not provide an accurate picture of overall hedgerow use. A second field season may have shown that individuals classified as permanent residents may also use the adjacent forest fragments while transients may disperse into adjacent forest fragments. A longer study may result in greater detection of interhabitat movements.

Our findings show that hedgerows are important to eastern chipmunks on Prince Edward Island. While the primary function of hedgerows is to provide benefits to landowners, they may also provide foraging and breeding habitat maintaining viable populations of eastern chipmunks. The large number of residents in hedgerows indicates that removal of hedgerows would have a negative impact on chipmunk populations in these areas. A previous study has also shown that many other small mammal species also occur in hedgerows (see Chapters 5 and 6). Although our results indicate that hedgerows may not function as movement corridors between forest fragments, young chipmunks produced in hedgerows may provide a necessary flow of individuals between forest fragments. Further investigation into the dispersal patterns of young produced in hedgerows and the exact movement paths of individuals in hedgerows are needed to better determine the importance of hedgerows as corridors for eastern chipmunks.

8. SUMMARY OF RESULTS AND CONCLUSIONS

The landscape of Prince Edward Island is highly fragmented with few areas of continuous forest remaining. Hedgerows are often the only connections between forest fragments. However, hedgerows are often removed to promote field expansion (Baudry *et al.* 2000). Although several studies have investigated the effects of fragmentation on small mammals (Silva 1999, Silva *et al.* 2000, Silva 2001), none have addressed the importance of hedgerows to small mammals. Several studies in many other fragmented landscapes have demonstrated that hedgerows are used by small mammals as breeding habitat, movement corridors, and extended foraging areas (Henderson *et al.* 1985, Bennett *et al.* 1994, Wauters *et al.* 1994, Henein *et al.* 1998). In order to better manage and conserve Prince Edward Island's mammalian fauna, it is important to determine what role hedgerows play in the landscape.

Overall, our findings suggest that hedgerows are an important habitat resource for small mammals on Prince Edward Island, primarily serving as breeding habitat and extended foraging areas. Conservation of long hedgerows (>400 m) may help maintain viable populations of small mammals, especially eastern chipmunks, throughout the island. While previous studies indicate that eastern chipmunks may not reach high abundances in Prince Edward Island (Bateman and Prescott 1984), our findings show that eastern chipmunks are both widespread and abundant within hedgerows and forest fragments. However, unlike in other agricultural landscapes (Henderson *et al.* 1985, Bennett *et al.* 1994, Henein *et al.* 1998), eastern chipmunks on Prince Edward Island only use hedgerows as extended habitat, both foraging and breeding habitat, and not as movement corridors. Other studies have found that hedgerows connecting forest fragments were used as movement pathways, maintaining the viability of eastern chipmunk populations in forest fragments (*e.g.*, Bennett *et al.* 1994). In our study areas, the lower abundance of eastern chipmunks in hedgerows connecting fragments suggests that movement may occur in these situations. However, actual movement of individuals between fragments was not detected. Eastern chipmunks were ubiquitous in terms of hedgerow selection indicating that they may have adapted well to the habitat conditions within hedgerows. All of the hedgerows selected for this study were established approximately 65 years ago, which may have given eastern chipmunks time to adapt to hedgerow conditions. Investigation into eastern chipmunk habitat selection in hedgerows of varying age would determine whether hedgerows must be present in the landscape for a long period of time before high abundances of eastern chipmunks within them are reached.

Several other small mammal species were captured in hedgerows, although none reached high abundances in either hedgerows or forest fragments. Several other small mammal species were captured within hedgerows, although none reached high abundances. One explanation for this may be that the trapping design used within hedgerows was not effective for capturing a wide variety of species. Only Sherman live-traps were used in this study and this may have resulted in an underestimation of trap shy species. A combination of live-traps and pitfall traps may have resulted in a more robust estimation of insectivores and small rodents such as the meadow jumping mouse and woodland jumping mouse.

Our results suggest that hedgerows may provide habitat for many woodland species as well as acting as refugia for species occurring in the surrounding landscape, such as the meadow jumping mouse, during crop harvest. The abundance of other small mammals species captured in hedgerows was determined by several microhabitat characteristics, with hedgerows containing the greatest variation in habitat structure (*e.g.*, a high proportion of gaps, variation in canopy cover) containing the greatest species richness. This was expected considering that previous studies have shown that small mammal species richness within hedgerows was positively associated with microhabitat complexity (Yahner 1982, Yahner 1983). However, several species, including the southern red-backed vole, northern flying squirrel, and common shrew, were far more abundant in forest fragments than hedgerows, suggesting that hedgerows may not provide as much habitat for all small mammal species. Previous studies (*e.g.*, Yahner 1992, Witt 1992) have shown that specific microhabitat features, such as large trees and a high abundance of logs, are important for these species. Management of the microhabitat features of hedgerows may increase the abundance of these species within hedgerows.

From a conservation and management perspective, hedgerows are important landscape features to many small mammal species on Prince Edward Island, especially the eastern chipmunk, and should be retained. However, since this study was limited to one field season and each site was only sampled for three days per month, small mammal abundance recorded within hedgerows may not adequately reflect actual small mammal abundance within hedgerows. Longer trapping sessions may have resulted in higher small mammal abundances, especially for species that were captured in low abundance. Nevertheless, our results show that 11 of the 15 species known to occur within forest fragments on Prince Edward Island also occur within hedgerow habitat, demonstrating that hedgerows are an important habitat resource for small mammals on the island. While hedgerows may not serve as corridors for eastern chipmunks, our results provide evidence that hedgerows are used by chipmunks as extended habitats. In areas with few large tracts of forest, such as much of central Prince Edward Island, hedgerow management that focuses on improvement of hedgerow microhabitat features may ultimately allow the persistence of small mammal communities in these landscapes. The majority of small mammal species encountered during this study were woodland species, therefore, increased abundances of these species in hedgerows, which are embedded in agricultural fields, is not expected to negatively affect crop production. While the eastern chipmunk was found to be abundant in both forest fragments and hedgerows, long-term persistence of this species may depend on the availability of hedgerows for extended foraging and breeding habitat. Further long-term studies that include a greater number of hedgerows as well as a greater variety of hedgerows (i.e., varying lengths, widths, and microhabitat conditions) are needed to fully understand small mammal use of hedgerows. Studies investigating the effect of hedgerow removal on small mammal communities would also be beneficial to future management of Prince Edward Island's fragmented landscape.

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10. APPENDIX A

Table 1. Capture data for Site 1, Prince Edward Island National Park. Note: Blank cells indicate that the information was not available; AM = morning; PM = afternoon; M = male; F = female; N = no; Y = yes.

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/12/01	AM	HA-25	*Napaeozapus/Zapus*						
07/18/01	PM	HC-13	*Tamias striatus*	2193	3372	M	87		Y
06/12/01	AM	HB-10	*Napaeozapus insignis*	2832	2980	M	20	Scrotal	
06/12/01	AM	HB-02	*Tamias striatus*	2833	2978	F	117	Nipples	N
06/12/01	AM	HB-11	*Napaeozapus insignis*	2834	2839		20		
06/12/01	PM	F5-20	*Tamias striatus*	2835	2990	F	83	N	N
06/13/01	PM	F5-11	*Tamias striatus*	2835	2990	F	84	N	Y
07/17/01	PM	F5-25	*Tamias striatus*	2835	2990	F	81	N	Y
06/12/01	PM	HA-20	*Tamias striatus*	2836	2984	F	89	N	N
07/17/01	PM	HA-15	*Tamias striatus*	2836	2984	F	84	N	Y
07/18/01	PM	HA-17	*Tamias striatus*	2836	2984	F	83	N	Y
09/15/01	AM	HA-19	*Tamias striatus*	2984		F	78	N	Y
06/12/01	AM	HC-34	*Tamias striatus*	2837	2986	F	90	Nipples	
06/12/01	PM	HC-33	*Tamias striatus*	2837	2986	F	84	Nipples	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/13/01	AM	HC-34	*Tamias striatus*	2837	2986	F			
06/13/01	PM	HC-34	*Tamias striatus*	2837	2986	F	86	Nipples	Y
07/17/01	PM	HC-36	*Tamias striatus*	2986	3302	F	82	Nipples	Y
07/18/01	PM	HC-34	*Tamias striatus*	2986	3302	F	76	Nipples	Y
09/15/01	AM	HC-36	*Tamias striatus*	2986		F	87	N	Y
06/12/01	PM	HB-10	*Tamias striatus*	2902	2987	M	97	Scrotal	N
06/12/01	PM	F5-02	*Tamias striatus*	2903	2904	M	91	Scrotal	N
06/12/01	PM	HB-08	*Tamias striatus*	2905	2906	M	113	Scrotal	N
06/12/01	PM	HB-04	*Tamias striatus*	2907	2972	M	115	Scrotal	N
06/13/01	PM	F5-02	*Tamias striatus*	2909	2910	F	81	Nipples	N
07/17/01	PM	F5-01	*Tamias striatus*	2909	3348	F	88	N	Y
06/12/01	PM	HC-16	*Tamias striatus*	2913	2914	M	90	Scrotal	N
06/13/01	AM	HC-16	*Tamias striatus*	2913	2914	M	103	Scrotal	Y
07/17/01	AM	HC-14	*Tamias striatus*	2913	3372	M	90	Scrotal	Y
08/21/01	PM	HC-12	*Tamias striatus*	3372	3437	M	100	N	Y
09/15/01	PM	HC-07	*Tamias striatus*	3372	3437	M	96	N	Y
06/12/01	PM	HC-03	*Tamias striatus*	2915	2951	M	90	Scrotal	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/13/01	PM	HC-03	*Tamias striatus*	2915	2951	M	97	Scrotal	Y
06/12/01	PM	HB-06	*Tamias striatus*	2916	2923	M	92	Scrotal	N
06/13/01	PM	F5-01	*Tamias striatus*	2916	2923	M	91	Scrotal	Y
06/12/01	AM	HB-01	*Zapus hudsonicus*	2924	2949	M	17	Scrotal	
06/12/01	AM	F5-24	*Peromyscus maniculatus*	2932	2982	M	24	Scrotal	
06/12/01	AM	HC-43	*Zapus hudsonius*	2933	2934	M	17	Scrotal	N
06/13/01	AM	HB-03	*Napaeozapus insignis*	2952	2953	M	15	Scrotal	N
06/13/01	PM	F5-22	*Tamias striatus*	2954	2955	F	83	N	N
07/17/01	PM	F5-21	*Tamias striatus*	2954	2955	F	86	N	Y
07/18/01	PM	F5-21	*Tamias striatus*	2954	2955	F	85	N	Y
09/15/01	AM	F5-21	*Tamias striatus*	2954	2955	F	91	N	Y
06/12/01	PM	HB-12	*Tamias striatus*	2965	2966	F	106	Nipples	N
06/12/01	PM	HC-34	*Tamias striatus*	2971	2991	F	103	Nipples	N
06/13/01	PM	HC-28	*Tamias striatus*	2971	2991	F	101	Nipples	Y
06/12/01	PM	F5-23	*Tamias striatus*	2973	2974	M	92	Scrotal	N
06/13/01	PM	F5-17	*Tamias striatus*	2973	2974	M	98	Scrotal	Y
07/17/01	AM	HB-11	*Tamias striatus*	2979	2993	F	99	Nipples	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/17/01	PM	HB-10	*Tamias striatus*	2979	2993	F	91	Nipples	Y
08/21/01	PM	HB-12	*Tamias striatus*	2979	2993	F	102		Y
07/17/01	PM	F5-08	*Tamias striatus*	2987	3324	M	95		Y
08/21/01	PM	HB-03	*Tamias striatus*	2987	3324	M	92	N	Y
08/22/01	PM	F5-03	*Tamias striatus*	2987	3324	M	96	N	Y
06/12/01	PM	HB-13	*Tamias striatus*	2988	2989	M	96	Scrotal	N
08/21/01	PM	HC-31	*Tamias striatus*	2988	3444	F	89	N	Y
08/22/01	PM	F5-24	*Tamias striatus*	2990	3473		93		Y
06/12/01	PM	F5-01	*Tamias striatus*	2992	2994	M	68	N	N
06/12/01	PM	HA-01	*Tamias striatus*	3056	3057	F	95	Nipples	Y
08/21/01	PM	HA-02	*Tamias striatus*	3057	3430	F	107	Nipples	Y
08/22/01	PM	HA-08	*Tamias striatus*	3057	3430	F	NA	NA	
06/13/01	PM	HC-46	*Tamias striatus*	3079	3080	M	87	Scrotal	N
07/17/01	AM	HA-16	*Peromyscus maniculatus*	3241	3291	M	20	Scrotal	N
08/22/01	AM	HA-16	*Peromyscus maniculatus*	3241	3291	M	23	N	Y
07/17/01	PM	F5-05	*Tamias striatus*	3301	3325	M	74	N	N
07/18/01	PM	F5-08	*Tamias striatus*	3301	3325	M	84	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/18/01	PM	HC-28	*Tamiasciurus hudsonicus*	3303	3304	M	121	N	N
07/18/01	PM	HC-47	*Tamias striatus*	3305	3306	M	62	N	N
07/17/01	PM	HC-13	*Tamias striatus*	3321	3322	M	83	N	N
07/18/01	PM	HC-05	*Tamias striatus*	3321	3322	M	77	N	Y
07/17/01	PM	HC-24	*Tamias striatus*	3323	3369	F	59	N	N
07/18/01	PM	HC-30	*Tamias striatus*	3323	3369	F	65	N	Y
07/17/01	PM	F5-17	*Tamias striatus*	3326	3327	F	73	NA	N
07/17/01	PM	F5-13	*Tamias striatus*	3344	3345	NA	57	N	N
07/17/01	PM	F5-12	*Tamias striatus*	3346	3347	M	103	Scrotal	N
08/21/01	PM	F5-11	*Tamias striatus*	3346	3347	M	102	N	Y
07/17/01	AM	HC-23	*Tamias striatus*	3349	3350	F	92	Nipples	Y
07/17/01	PM	HC-20	*Tamias striatus*	3349	3350	F	84	Nipples	Y
07/18/01	PM	HC-18	*Tamias striatus*	3349	3350	F	79	Nipples	Y
08/22/01	PM	HC-20	*Tamias striatus*	3349	3470	F	91	N	Y
09/15/01	AM	HC-22	*Tamias striatus*	3349		F	87	N	Y
09/15/01	PM	HC-22	*Tamias striatus*	3349		F	87	N	Y
07/17/01	PM	HB-04	*Tamias striatus*	3351	3352	F	69	N	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/17/01	PM	HB-13	*Tamias striatus*	3353	3354	M	65	N	N
07/18/01	PM	HA-01	*Tamias striatus*	3355	3356	M	113	Scrotal	Y
08/21/01	PM	HA-08	*Tamias striatus*	3355	3431	M	100	N	Y
07/18/01	PM	F5-01	*Tamias striatus*	3357	3358	M	75	N	N
07/18/01	PM	F5-23	*Tamias striatus*	3359	3360	F	80	N	N
07/18/01	PM	F5-05	*Tamias striatus*	3361	3362	M	89	Scrotal	N
07/18/01	PM	HA-15	*Tamias striatus*	3363	3364	F	68	N	N
07/17/01	PM	HC-47	*Tamias striatus*	3365	3366	M	87	N	N
07/17/01	PM	HB-05	*Tamias striatus*	3367	3368	F	87	Nipples	N
07/18/01	PM	HB-04	*Tamias striatus*	3367	3368	F	86	Nipples	Y
07/17/01	PM	F5-19	*Tamias striatus*	3370	3371	M	87	Scrotal	N
07/17/01	AM	F5-16	*Tamias striatus*	3373	3374	M	83	N	N
07/17/01	PM	F5-16	*Tamias striatus*	3373	3374	M	79	N	Y
07/18/01	PM	F5-16	*Tamias striatus*	3373	3374	M	77	N	Y
09/15/01	PM	HB-02	*Tamias striatus*	3373	3374	M	85	NA	Y
07/17/01	AM	F5-05	*Tamias striatus*	3375		F	96	NA	Y
07/18/01	AM	F5-05	*Tamias striatus*	3375		F	98	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/17/01	PM	F5-23	*Tamias striatus*	3376	3377	M	78	N	N
09/15/01	PM	F5-21	*Tamias striatus*	3377		M	86	N	Y
07/17/01	PM	HC-11	*Tamias striatus*	3378	3379	F	84	N	N
07/18/01	AM	HC-13	*Tamias striatus*	3378	3379	F	83	N	Y
07/18/01	PM	HC-12	*Tamias striatus*	3378	3379	F	83	NA	Y
08/21/01	PM	HC-08	*Tamias striatus*	3378	3379	F	93	N	Y
08/22/01	AM	HC-09	*Tamias striatus*	3378	3379	F	92	NA	Y
08/22/01	PM	HC-02	*Tamias striatus*	3378	3379	F	82	N	Y
07/17/01	PM	HA-04	*Tamias striatus*	3399	3400	M	75	N	N
08/21/01	AM	F5-18	*Napaeozapus insignis*	3422	3425	F	25	N	N
08/22/01	AM	F5-18	*Napaeozapus insignis*	3422	3425	M	28	N	Y
08/21/01	AM	F5-07	*Tamias striatus*	3423	3424	M	110	N	N
08/22/01	AM	F5-06	*Tamias striatus*	3423	3424	M	101	N	Y
08/21/01	AM	F5-21	*Tamias striatus*	3426	3427		101	NA	Y
08/21/01	PM	F5-16	*Tamias striatus*	3426	3427	F	83	N	Y
08/21/01	AM	F5-22	*Napaeozapus insignis*		3428	F	30	Pregnant	N
08/21/01	PM	HC-11	*Tamias striatus*	3432	3433		75	N	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
08/22/01	PM	HC-12	*Tamias striatus*	3432	3433			NA	
07/17/01	PM	F5-02	*Tamias striatus*	3520	3521	M	82	N	Y
08/21/01	PM	F5-04	*Tamias striatus*	3434	3521	M	92	N	Y
08/21/01	PM	HC-01	*Tamias striatus*	3435	3436	M	92	N	Y
09/15/01	AM	HC-01	*Tamias striatus*	3435	3436	M	84	N	Y
08/21/01	PM	HC-25	*Tamias striatus*	3438	3439	F	83	N	Y
09/15/01	PM	HC-28	*Tamias striatus*	3438	3439	F	80	N	Y
08/21/01	PM	HC-38	*Tamias striatus*	3442	3443	M	86	NA	
09/15/01	PM	HC-48	*Tamias striatus*	3442	3443	M	87	N	Y
08/21/01	PM	HB-06	*Tamias striatus*	3445	3450	F	86	N	Y
08/22/01	PM	HB-06	*Tamias striatus*	3445	3450	NA	91	NA	Y
09/15/01	PM	HB-08	*Tamias striatus*	3445	3450	F	90	N	Y
08/21/01	PM	HB-13	*Tamias striatus*	3446	3447	F	87	N	N
09/15/01	PM	HB-13	*Tamias striatus*	3446	3447	F	92	NA	Y
08/21/01	PM	F5-23	*Tamias striatus*	3449	3448	M	101	N	N
08/22/01	AM	F5-08	*Glaucomys sabrinus*	3451	3452	M	79	N	N
08/22/01	AM	F5-13	*Tamias striatus*	3453	3680	F	92	N	Y

Date	Time	Trap	Species	Tag #	Sex	Mass (g)	Reproductive Condition	Recapture
09/15/01	AM	HB-11	*Tamias striatus*	4017	F	80	N	Y
09/15/01	PM	F5-23	*Tamias striatus*		F	86	N	Y
09/15/01	AM	F5-06	*Glaucomys sabrinus*	4018	M	73	N	N
09/15/01	PM	HB-11	*Tamias striatus*	4049	M	91	N	N
09/15/01	PM	HC-08	*Tamiasciurus hudsonicus*	4056	F	130	N	N
07/17/01	PM	F5-10	*Tamias striatus*		NA	NA	NA	
08/21/01	AM	HC-33	*Mustela erminea*		NA	NA	NA	
08/21/01	AM	HC-37	*Blarina brevicauda*		F	17	Nipples	N
08/21/01	AM	HC-49	*Blarina brevicauda*		F	17	N	N
08/21/01	PM	HA-21	*Mustela erminea*		NA	NA	NA	
09/15/01	AM	HC-38	*Shrew sp.*		NA	3.5	N	N
09/15/01	AM	HC-30	*Zapus hudsonius*		M	12	N	N
09/15/01	AM	HC-32	*Blarina brevicauda*		NA	12	N	N
09/15/01	AM	HC-41	*Blarina brevicauda*		NA	16	N	N
09/15/01	AM	HB-13	*Blarina brevicauda*		NA	18	NA	N
09/15/01	AM	HA-05	*Mustela erminea*		NA	NA	NA	
09/15/01	PM	HC-42	*Microtus pennsylvanicus*		NA	24	NA	N

Table 2. Capture data for Site 2, Macphail Woods. Note that blank cell indicate the information was not available.

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
05/22/0	AM	F3-13	*Tamiasciurus hudsonicus*	2874	2895	M	60	N	N
05/22/0	PM	HB-3	*Tamiasciurus hudsonicus*	1312	2034	M	139	Scrotal	Y
06/26/0	PM	F2-03	*Tamiasciurus hudsonicus*	1312	2034	M	139	Scrotal	Y
06/27/0	PM	F2-13	*Tamiasciurus hudsonicus*	1312	NA	NA	NA	NA	NA
05/22/0	PM	F1-6	*Tamias striatus*	2012	2886	M	90	Scrotal	N
05/22/0	PM	F1-20	*Clethrionomys gapperi*	2031	2796	M	27	Scrotal	N
05/22/0	PM	F4-22	*Clethrionomys gapperi*	2035	2800	M	28	N	N
05/22/0	PM	F3-8	*Clethrionomys gapperi*	2036	2862	M	22	N	N
05/23/0	PM	F2-5	*Tamiasciurus hudsonicus*	2038	2792	M	141	Scrotal	N
05/23/0	PM	F1-12	*Tamias striatus*	2040	2862	M	96	Scrotal	N
06/26/0	AM	F1-02	*Tamias striatus*	2040	2862	M	97	Scrotal	Y
06/27/0	PM	F1-11	*Tamias striatus*	2040	2862	M	92	Scrotal	Y
09/03/0	AM	F1-12	*Tamias striatus*	2040	2862	M	95	N	Y
07/24/0	AM	F1-11	*Tamias striatus*	2042	2862	M	98	N	Y
05/23/0	PM	F2-20	*Tamias striatus*	2045	2863	M	85	Scrotal	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/26/0	PM	F2-15	*Tamias striatus*	2045	2863	M	89	Scrotal	Y
07/24/0	PM	F2-19	*Tamias striatus*	2045	2863	M	89	N	Y
09/03/0	NA	F5-16	*Clethrionomys gapperi*	2478	NA	M	20	N	N
09/03/0	AM	HA-25	*Peromyscus maniculatus*	2498	NA	M	18	N	
05/23/0	PM	F1-5	*Microtus pennsylvanicus*	2685	2836	M	30	N	N
05/23/0	PM	F1-4	*Tamias striatus*	2686	2873	F	85	N	N
05/23/0	AM	F1-10	*Clethrionomys gapperi*	2767	2892	M	43	Scrotal	N
05/22/0	PM	HA-24	*Tamias striatus*	2776	3000	M	66	Scrotal	N
05/22/0	AM	F4-24	*Clethrionomys gapperi*	2779	2794	M	29	Scrotal	N
05/23/0	AM	F4-22	*Clethrionomys gapperi*	2779	2977	M	30	Scrotal	Y
05/23/0	PM	F1-23	*Tamiasciurus hudsonicus*	2780	2898	F	163	Pregnant	N
05/22/0	PM	F2-20	*Tamias striatus*	2789	2865	M	82	Scrotal	N
06/26/0	PM	F2-02	*Tamias striatus*	2789	2865	M	89	Scrotal	Y
05/22/0	AM	F2-20	*Glaucomys sabrinus*	2790	2848	M	111	N	N
05/22/0	PM	F1-7	*Tamias striatus*	2823	2855	M	108	Scrotal	N
06/27/0	PM	F1-07	*Tamias striatus*	2823	2855	M	95	Scrotal	Y
06/26/0	PM	F1-07	*Tamiasciurus hudsonicus*	2831	2919	M	154	Scrotal	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
05/23/0	PM	HB-2	*Tamias striatus*	2852	2876	F	89	Nipples	N
05/22/0	AM	HC-38	*Microtus*	2857	2888	M	38	Scrotal	N
05/23/0	PM	F4-14	*Tamias striatus*	2859	2863	NA	NA	NA	N
05/22/0	PM	F4-23	*Clethrionomys gapperi*	2860	2900	M	18	N	N
05/23/0	PM	F4-25	*Clethrionomys gapperi*	2860	2900	M	16	N	Y
06/26/0	AM	HB-02	*Tamias striatus*	2896	3025	F	89	Nipples	Y
06/26/0	PM	F1-08	*Tamias striatus*	2896	3025	F	85	Nipples	Y
06/27/0	AM	F1-08	*Tamias striatus*	2896	3025	F	85	Nipples	Y
06/27/0	PM	HB-04	*Tamias striatus*	2896	3025	F	86	Nipples	Y
06/27/0	AM	F5-01	*Tamiasciurus hudsonicus*	2908	3004	M	149	N	NA
06/26/0	AM	F1-05	*Clethrionomys gapperi*	2911	2912	M	17	Scrotal	N
06/26/0	AM	F4-25	*Clethrionomys gapperi*	2917	2920	M	26	Scrotal	N
06/26/0	PM	F1-09	*Tamias striatus*	2918	3046	M	56	N	N
06/27/0	PM	HB-01	*Tamias striatus*	2918	3046	M	50	NA	Y
06/26/0	PM	F1-18	*Tamias striatus*	2921	2958	F	55	N	N
06/27/0	PM	F1-06	*Tamias striatus*	2921	2958	F	75	NA	NA
07/24/0	PM	F1-21	*Tamias striatus*	2921	2958	F	73	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
09/03/0	AM	F1-21	*Tamias striatus*	2921	2958	F	65	N	Y
06/26/0	PM	HC-12	*Tamias striatus*	2922	3063	M	79	Scrotal	N
06/27/0	PM	HC-12	*Tamias striatus*	2922	3063	M	86	NA	Y
07/24/0	AM	HC-12	*Tamias striatus*	2922	3063	M	91	Scrotal	Y
07/25/0	PM	HC-13	*Tamias striatus*	2922	3063	M	89	Scrotal	Y
05/23/0	AM	HC-18	*Glaucomys sabrinus*	2925	2939	F	109	Nipples	N
05/23/0	AM	F4-23	*Clethrionomys gapperi*	2940	2945	M	22	NA	NA
05/22/0	PM	F5-3	*Tamias striatus*	2948	2950	M	102	Scrotal	N
07/24/0	AM	F3-10	*Tamias striatus*	2948	3314	M	94	N	Y
06/26/0	AM	HC-12a	*Glaucomys sabrinus*	2956	2957	F	88	Nipples	N
06/26/0	PM	HC-01	*Tamias striatus*	2960		M	86	Scrotal	N
07/25/0	PM	HC-02	*Tamias striatus*	2960	3386	M	87	Scrotal	Y
06/26/0	PM	HC-09	*Tamias striatus*	2961	2962	M	83	Scrotal	N
06/27/0	PM	HC-18	*Tamias striatus*	2961	2970	M	89	Scrotal	Y
06/27/0	PM	HC-09	*Tamias striatus*	2963	2964	M	69	N	Y
06/26/0	PM	HC-10	*Tamias striatus*	2964	2965	M	74	N	N
06/26/0	PM	HC-34	*Tamias striatus*	2968	3053	F	83	Nipples	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/27/0	PM	HC-34	*Tamias striatus*	2968	3053	F	NA	Scrotal	Y
06/26/0	AM	HC-38	*Tamias striatus*	3053		F	90	Nipples	N
07/24/0	PM	HC-33	*Tamias striatus*	3053	3332	F	89	Nipples	Y
07/25/0	PM	F4-12	*Tamias striatus*	3053	3332	F	84	Nipples	Y
09/03/0	PM	HC-34	*Tamias striatus*	3053	3332	F	88	N	Y
06/26/0	PM	HC-18	*Tamias striatus*	2969	2970	M	100	Scrotal	N
07/24/0	PM	HC-18	*Tamias striatus*	2969	2970	M	97	N	Y
07/25/0	PM	HC-18	*Tamias striatus*	2969	2970	M	97	Scrotal	Y
05/23/0	PM	HA-24	*Tamias striatus*	2976	3000	M	96	Scrotal	Y
06/26/0	AM	HA-23	*Tamias striatus*	3000	2976	M	100	Scrotal	Y
06/26/0	PM	HA-21	*Tamias striatus*	2976	3000	M	91	Scrotal	Y
06/27/0	PM	HA-21	*Tamias striatus*	2976	3000	NA	91	NA	NA
07/24/0	PM	HA-19	*Tamias striatus*	2976	3000	M	91	Scrotal	Y
07/25/0	PM	HA-19	*Tamias striatus*	2976	3000	M	92	N	Y
09/03/0	PM	HA-19	*Tamias striatus*	2976	3000	M	87	N	Y
06/27/0	AM	F2-11	*Tamias striatus*	2983	3088	M	54	N	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/27/0	PM	HB-20	*Tamiasciurus hudsonicus*	3040	3041	M	150	Scrotal	N
06/26/0	PM	F4-17	*Tamias striatus*	3042	3043	M	103	NA	N
06/27/0	PM	F4-20	*Tamias striatus*	3042	3043	M	102	NA	Y
09/03/0	PM	F4-16	*Tamias striatus*	3043	NA	M	96	NA	Y
06/26/0	PM	F4-25	*Tamias striatus*	3045	3046	M	90	Scrotal	N
07/24/0	PM	F1-09	*Tamias striatus*	3046	3343	F	70	N	Y
09/03/0	PM	F1-18	*Tamias striatus*	3046	NA	NA	75	N	Y
06/26/0	AM	F5-22	*Tamiasciurus hudsonicus*	3061	3083	M	NA	Scrotal	NA
07/24/0	AM	F5-24	*Tamiasciurus hudsonicus*	3061	NA	M	141	Scrotal	Y
06/26/0	PM	HB-12	*Tamias striatus*	3086	3087	M	86	N	N
06/27/0	PM	F2-02	*Tamias striatus*	3086	3087	NA	93	NA	NA
06/26/0	AM	HA-05	*Clethrionomys gapperi*	3089	3090	M	18	Scrotal	N
06/27/0	AM	?-4	*Clethrionomys gapperi*	3089	3090	M	18	Scrotal	Y
06/26/0	PM	F5-09	*Tamiasciurus hudsonicus*	3091		M	155	Scrotal	NA
06/27/0	PM	F5-09	*Tamiasciurus hudsonicus*	3091	NA	M	135	Scrotal	Y
06/26/0	AM	F1-13	*Clethrionomys gapperi*	3093	3096	M	37	Scrotal	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/25/0	AM	F5-06	*Tamias striatus*	3333	3334	M	76	N	Y
07/25/0	PM	F5-06	*Tamias striatus*	3333	3334	M	71	N	Y
09/03/0	PM	F5-01	*Tamias striatus*	3333		M	81	N	Y
07/25/0	AM	F5-04	*Peromyscus maniculatus*	3335	3337	M	17	Scrotal	N
07/24/0	PM	F5-24	*Clethrionomys gapperi*	3338	3339	M	14	Scrotal	N
07/24/0	PM	HC-31	*Tamiasciurus hudsonicus*	3340	3342	M	106	N	N
07/25/0	PM	F1-17	*Tamias striatus*	3380	3381	F	55	N	N
07/25/0	PM	F2-10	*Clethrionomys gapperi*	3382	3383	M	21	Scrotal	N
07/25/0	PM	HC-11	*Tamias striatus*	3384	3385	M	78	N	N
09/03/0	PM	F2-13	*Tamias striatus*	3386		M	89	N	Y
07/25/0	AM	HA-07	*Clethrionomys gapperi*	3397	3398	M	15	Scrotal	N
09/03/0	PM	F3-12	*Clethrionomys gapperi*	3479		M	17		Y
05/23/0	AM	F5-17	*Tamiasciurus hudsonicus*			M	144	N	N
05/23/0	AM	F3-11	*Napaeozapus insignis*			M	16	Scrotal	N
06/26/0	AM	HA-21	*Peromyscus maiculatus*			M	14	Scrotal	N
06/26/0	AM	F4-15	*Tamias striatus*				105		N

Date	Time	Trap	Species	Tag #	Sex	Mass (g)	Reproductive Condition	Recapture
06/26/0	AM	F1-22	*Sorex sp.*			4.5		
06/26/0	AM	F3-14	*Glaucomys sabrinus*		M	80	Scrotal	N
06/26/0	PM	F3-09	*Clethrionomys gapperi*		M	11	N	N
06/26/0	PM	HC-25	*Tamias striatus*					
06/27/0	AM	F5-22	*Sorex sp.*			5		
06/27/0	PM	F1-05	*Clethrionomys gapperi*		M	18	Scrotal	N
06/27/0	PM	HC-20a	*Tamiasciurus hudsonicus*		F		Nipples	N
07/25/0	AM	F3-14	*Blarina brevicauda*			17		N
07/25/0	AM	F1-05	*Sorex sp.*			5		N
07/25/0	PM	F1-24	*Clethrionomys gapperi*		M	15	Scrotal	N
09/03/0	AM	F4-08	*Sorex sp.*			3		
09/03/0	AM	HB-08	*Sorex sp.*			3.5		
09/03/0	AM	F1-24	*Sorex sp.*			3.5		N
09/03/0	AM	HA-14	*Sorex sp.*			4		
09/03/0	PM	HC-25	*Tamias striatus*		F	75	N	N
09/03/0	PM	HC-14	*Tamias striatus*		M	81	N	N

Date	Time	Trap	Species	Tag #	Sex	Mass (g)	Reproductive Condition	Recapture
09/03/0	PM	F2-01	*Tamias striatus*		F	62	N	N
09/03/0	PM	F1-09	*Tamias striatus*		F	81	N	N
09/03/0	PM	F3-05	*Blarina brevicauda*			15		
09/03/0	AM	F1-13	*Clethrionomys gapperi*	3476	M	18	N	Y
09/03/0	AM	F4-22	*Clethrionomys gapperi*	3477	M	19	N	N
09/03/0	AM	F3-07	*Clethrionomys gapperi*	3479	M	18	N	N
09/03/0	PM	F4-22	*Sorex sp.*			4		N
09/03/0	PM	F4-24	*Tamias striatus*		M	86	N	N
09/03/0	PM	F4-25	*Tamias striatus*		M	76	N	N
07/24/0	AM	F4-12	*Mustela erminea*					
09/03/0	PM	F1-10	*Mustela erminea*					

Table 3. Capture data for Site 3, Pleasant Grove. Note that blank cells indicate that information was not available.

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
05/29/01	AM	HA-57	*Tamisciurus hudsonicus*	2675	2938	M	163	Scrotal	N
05/29/01	PM	HA-31	*Tamias striatus*	1322	2822	M	88	Scrotal	Y
07/03/01	AM	HA-40	*Tamias striatus*	2063	3017	M	98	Scrotal	Y
07/03/01	PM	HA-67	*Tamias striatus*	2103	3113	F	85	N	N
05/30/01	PM	HA-32	*Tamias striatus*	2322	2899	F	80	N	Y
05/30/01	AM	F2-14	*Clethrionomys gapperi*	2765	2867		25		Y
05/30/01	AM	F2-17	*Tamias striatus*	2766	2889	F	88	N	N
07/03/01	PM	HB-10	*Tamias striatus*	2766	3104	F	91	Nipples	
07/04/01	PM	F2-06	*Tamias striatus*	2766	3104	F	89	Nipples	Y
07/31/01	AM	F2-17	*Tamias striatus*	2766	3389	F	96	Nipples	Y
08/01/01	PM	F2-06	*Tamias striatus*	2766	3389	F	97	Nipples	
09/01/01	AM	F2-11	*Tamias striatus*	2766	3389	F	98	N	Y
05/29/01	PM	F2-2	*Clethrionomys gapperi*	2778	2867	M	23	Scrotal	N
05/30/01	PM	F1-12	*Tamias striatus*	2828	2829	F	79	N	N
05/30/01	PM	HA-44	*Tamias striatus*	2830	2841	F	92	Nipples	N
07/03/01	AM	HA-46	*Tamias striatus*	2830	2966	F	98	Nipples	Y

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
07/03/01	PM	HA-46	*Tamias striatus*	2830	2966	F	89	Nipples	Y
07/04/01	AM	HA-57	*Tamias striatus*	2830	2966	F	100	Nipples	Y
07/04/01	PM	HA-52	*Tamias striatus*	2830	2966	F	92	Nipples	Y
07/31/01	AM	HA-41	*Tamias striatus*	2830	3264	F	102	Nipples	Y
07/31/01	PM	HA-41	*Tamias striatus*	2830	3264	F	100		Y
08/01/01	AM	HA-44	*Tamias striatus*	2830	3264	F	103		
09/01/01	PM	HA-38	*Tamias striatus*	3264		F			Y
05/30/01	AM	HA-1	*Clethrionomys gapperi*	2840	2847	M	22	N	N
05/30/01	PM	F1-02	*Tamias striatus*	2840	2854	M	85	Scrotal	N
05/29/01	PM	F2-19	*Tamias striatus*	2851	2856	M	88	Scrotal	N
05/30/01	PM	F1-20	*Tamias striatus*	2851	2856	M	88	Scrotal	Y
05/29/01	PM	HA-70	*Tamias striatus*	2853	2871	M	90	Scrotal	N
05/30/01	PM	HA-69	*Tamias striatus*	2853	2871				Y
05/30/01	PM	HA-20	*Tamias striatus*	2854	2866	F	79	Nipples	Y
07/04/01	AM	F1-04	*Tamias striatus*	2854	3109	M	90	Scrotal	Y
07/04/01	PM	HA-24	*Tamias striatus*	2854	3109	M			
05/29/01	PM	HA-22	*Tamias striatus*	2857	2866	F	79	Nipples	N
05/30/01	PM	F3-9	*Tamias striatus*	2858	2897	M	63	Scrotal	N

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
07/03/01	PM	HC-11	*Tamias striatus*	2858	2897	M	90	Scrotal	Y
05/29/01	PM	F3-19	*Clethrionomys gapperi*	2864	2869	M	23	Scrotal	N
05/30/01	AM	F3-19	*Clethrionomys gapperi*	2864	2869	M	25	Scrotal	Y
05/29/01	PM	HA-41	*Tamias striatus*	2868	2891	M	86	Scrotal	N
05/30/01	PM	HA-28	*Tamias striatus*	2868	2891	M	87	Scrotal	Y
07/03/01	PM	HA-43	*Tamias striatus*	2868	3017	M	84	Scrotal	Y
07/04/01	AM	HA-?	*Tamias striatus*	2868	3017	M			
07/04/01	PM	HA-41	*Tamias striatus*	2868	3017	M			Y
05/29/01	AM	F2-6	*Peromyscus maniculatus*	2870		M	12	Scrotal	N
05/30/01	AM	F2-6	*Peromyscus maniculatus*	2870			16		Y
05/30/01	PM	F3-15	*Clethrionomys gapperi*	2872	2890	M	25	Scrotal	N
05/30/01	PM	F2-1	*Tamias striatus*	2875	2975	M	88	Scrotal	N
07/03/01	PM	F1-04	*Tamias striatus*	2875	2975	M	93	Scrotal	Y
07/04/01	PM	F1-12	*Tamias striatus*	2875	2975	M	101	Scrotal	Y
07/31/01	PM	F1-10	*Tamias striatus*	2875	2975	M	89	N	Y
08/01/01	PM	F1-19	*Tamias striatus*	2875	2975	M	95	N	Y
07/03/01	AM	F1-18	*Clethrionomys gapperi*	2967	3010	M	30	Scrotal	N
07/03/01	AM	HB-11	*Peromyscus maniculatus*	3001	3014	M	20	Scrotal	N

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
07/03/01	AM	HA-33	*Tamisciurus hudsonicus*	3003	3036	M	145	Scrotal	
07/04/01	PM	HA-31	*Tamisciurus hudsonicus*	3003	3036	M	146	Scrotal	Y
07/03/01	AM	HA-31	*Tamias striatus*	3011	3037	F	100	N	Y
07/03/01	PM	HA-34	*Tamias striatus*	3011	3037	F	86	Nipples	Y
07/04/01	AM	HA-35	*Tamias striatus*	3011	3037	F	88	N	Y
07/04/01	PM	HA-28	*Tamias striatus*	3011	3037				
07/03/01	AM	F1-01	*Clethrionomys gapperi*	3012	3039	M	22	Scrotal	N
07/03/01	AM	HA-01	*Tamias striatus*	3015	3016	F	95	Nipples	N
07/03/01	PM	F1-02	*Tamias striatus*	3015	3016	F	90	Nipples	Y
07/04/01	PM	F1-09	*Tamias striatus*	3015	3016	F	84	Nipples	Y
07/31/01	PM	F1-04	*Tamias striatus*	3015	3016	F	95	Y	Y
08/01/01	PM	F1-14	*Tamias striatus*	3015	3016	F	95	Nipples	Y
09/01/01	PM	HA-04	*Tamias striatus*	3015	3016	F			Y
07/03/01	AM	F1-04	*Clethrionomys gapperi*	3019	3038	M	21	Scrotal	N
07/03/01	AM	F3-23	*Tamias striatus*	3101	3102	M	81	Scrotal	N
07/03/01	PM	HB-01	*Tamias striatus*	3105	3106	F	84	N	N
07/04/01	AM	HA-10	*Tamias striatus*	3105	3106	F	90	N	Y
07/04/01	PM	HA-15	*Tamias striatus*	3105	3106		85		Y

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
07/04/01	AM	F1-01	*Clethrionomys gapperi*	3108	3107	M	18	N	Y
07/04/01	PM	F1-02	*Clethrionomys gapperi*	3107	3108	M	18	N	Y
07/04/01	AM	HA-24	*Peromyscus maniculatus*	3110	3146	M	12	N	N
07/04/01	AM	F3-23	*Peromyscus maniculatus*	3111	3112	M	17	N	N
07/03/01	PM	HA-59	*Tamisciurus hudsonicus*	3114	3115	M	80	Scrotal	N
07/03/01	PM	F3-21	*Tamisciurus hudsonicus*	3116	3117	F	144	N	N
09/01/01	AM	F3-21	*Tamisciurus hudsonicus*	3117	3469		133	N	Y
07/03/01	PM	F3-19	*Tamias striatus*	3118	3119	F	75	N	N
07/04/01	PM	HC-09	*Tamias striatus*	3118	3119	F	76	N	Y
07/31/01	PM	F3-19	*Tamias striatus*	3118	3119	F	81	N	Y
08/01/01	PM	F3-20	*Tamias striatus*	3118	3119	F	92	N	Y
07/03/01	PM	F3-23	*Tamias striatus*	3120	3121	M	70	N	N
07/04/01	PM	HC-09	*Tamias striatus*	3120	3121	M	68	N	Y
07/03/01	PM	F3-07	*Tamias striatus*	3122	3123	F	75	Nipples	N
07/04/01	PM	HC-12	*Tamias striatus*	3122	3123	F	76	N	Y
07/31/01	PM	F3-11	*Tamias striatus*	3122	3123	F	83	N	Y
07/31/01	PM	F3-11	*Tamias striatus*	3122	3133	F	79	N	Y
09/01/01	PM	F3-01	*Tamias striatus*	3122					Y

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
07/03/01	AM	F3-12	*Clethrionomys gapperi*	3124	3125	M	25	Scrotal	Y
07/03/01	AM	HA-69	*Peromyscus maniculatus*	3126	3127	M	20	Scrotal	N
07/03/01	PM	HA-15	*Tamias striatus*	3128	3129	M	83	Scrotal	N
07/04/01	PM	HA-14	*Tamias striatus*	3128	3129	M			Y
07/03/01	PM	HA-21	*Tamias striatus*	3130	3131	F	89	N	Y
07/04/01	PM	HA-27	*Tamias striatus*	3130	3131				
07/31/01	PM	HA-17	*Tamias striatus*	3130	3246	F	90	N	Y
07/04/01	AM	HA-52	*Glaucomys sabrinus*	3133	3132	M	100	Scrotal	N
07/04/01	AM	HA-65	*Tamiasciurus hudsonicus*	3134	3135		82	N	
07/04/01	PM	F1-14	*Tamias striatus*	3136	3137	M	88	Scrotal	N
08/01/01	PM	HA-23	*Tamias striatus*	3136	3137	M	85	N	Y
09/01/01	PM	F2-02	*Tamias striatus*	3136					Y
07/04/01	PM	HA-40	*Tamias striatus*	3138	3139	M	70	N	N
07/31/01	PM	F3-09	*Tamias striatus*	3138	3248	M	82	N	Y
09/01/01	AM	F3-04	*Tamias striatus*	3138	3248	M	89	N	Y
09/01/01	PM	F3-04	*Tamias striatus*	3138	3248	M	105		Y
07/03/01	PM	F1-09	*Clethrionomys gapperi*	3149		M	17	Scrotal	N
07/04/01	PM	HB-24	*Clethrionomys gapperi*	3140	3149	M	16	Scrotal	Y

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
07/04/01	PM	F1-09	*Tamias striatus*	3141	3176	F	90	Nipples	N
07/04/01	PM	HB-16	*Tamias striatus*	3144	3145	M	69	N	N
07/04/01	AM	F3-09	*Tamisciurus hudsonicus*	3147	3148	M	151	Scrotal	N
07/31/01	AM	F3-05	*Tamisciurus hudsonicus*	3147	3148	M	147	Scrotal	Y
07/04/01		F1-04	*Clethrionomys gapperi*	3151	3152	M	24	Scrotal	N
07/04/01	PM	HA-35	*Tamisciurus hudsonicus*	3153	3154	M	138	Scrotal	N
07/04/01	PM	HA-68	*Tamisciurus hudsonicus*	3175	3192	M	162	Scrotal	N
07/31/01	PM	HA-70	*Tamisciurus hudsonicus*	3175	3192	M			Y
07/31/01	PM	HA-70	*Tamisciurus hudsonicus*	3175	3192	M	158	Scrotal	Y
07/31/01	PM	HA-73	*Tamias striatus*	3223	3290	F	87		Y
08/01/01	AM	HA-70	*Tamias striatus*	3223	3290	F			Y
08/01/01	PM	HA-67	*Tamias striatus*	3223	3290	F			Y
08/01/01	AM	F2-06	*Peromyscus maniculatus*	3226	3249	M	28	Scrotal	N
08/01/01	AM	HA-67	*Zapus hudsonius*	3227	3250	F	17	Nipples	N
08/01/01	PM	HB-07	*Tamias striatus*	3227	3265	M	66	N	
07/31/01	PM	F3-16	*Tamias striatus*	3231	3287	M	76	N	N
08/01/01	PM	F3-11	*Tamias striatus*	3231	3287	M	74	N	Y
07/31/01	PM	F2-16	*Tamias striatus*	3232	3243	F	64	N	N

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
08/01/01	AM	HB-07	*Tamias striatus*	3232	3243	F	70		Y
08/01/01	PM	F2-13	*Tamias striatus*	3232	3243	F	73	N	Y
07/31/01	AM	HA-43	*Tamias striatus*	3233	3247	F	80	N	N
08/01/01	PM	HA-53	*Tamias striatus*	3233	3247	F	74	N	Y
09/01/01	PM	HA-43	*Tamias striatus*	3233					Y
07/31/01	PM	F3-24	*Tamias striatus*	3234	3236	M	78	Y	Y
08/01/01	PM	F3-17	*Tamias striatus*	3234	3236	M	82	N	Y
07/31/01	AM	HA-38	*Tamias striatus*	3235	3245	F	87	N	Y
07/31/01	PM	HA-37	*Tamias striatus*	3235	3245	F	93	N	Y
08/01/01	PM	HC-08	*Tamias striatus*	3235	3245	F	89		Y
09/01/01	PM	HA-32	*Tamias striatus*	3235	3245	F		N	Y
08/01/01	AM	HA-48	*Zapus hudsonius*	3237			18		
07/31/01	AM	HA-53	*Tamias striatus*	3238	3289	F	86	N	N
07/31/01	PM	HA-53	*Tamias striatus*	3238	3289	F	84		
08/01/01	PM	HA-55	*Tamias striatus*	3238	3289	F			Y
07/31/01	AM	HA-70	*Peromyscus maniculatus*	3239	3244	M	19	Scrotal	Y
08/01/01	PM	HA-58	*Tamias striatus*	3253	3269	M	82	N	N
08/01/01	PM	HA-65	*Zapus hudsonius*	3266	3268	F	17	Nipples	N

Date	Time	Trap	Species	Tag		Sex	Mass (g)	Reproductive Condition	Recapture
08/01/01	PM	F3-15	*Clethrionomys gapperi*	3270	3271	F	27	N	N
09/01/01	PM	HA-70	*Tamias striatus*	3270					
08/01/01	PM	F1-05	*Tamias striatus*	3272	3273	F	73	N	N
07/31/01	AM	F3-12	*Clethrionomys gapperi*	3387	3388	M	25	N	Y
07/31/01	AM	HA-10	*Peromyscus maniculatus*	3390		M	20	Scrotal	Y
09/01/01	AM	F3-20	*Peromyscus maniculatus*	3390		M	19	Scrotal	Y
07/31/01	AM	HA-06	*Tamisciurus hudsonicus*	3391	3392	F	120	N	N
07/31/01	AM	HB-06	*Tamias striatus*	3393	3394	M	71	N	N
07/31/01	PM	HB-02	*Tamias striatus*	3393	3394	M	72		Y
08/01/01	PM	HA-14	*Tamias striatus*	3393	3394	M			Y
07/31/01	AM	HB-08	*Tamias striatus*	3395	3396	F	91	N	Y
07/31/01	PM	HA-15	*Tamias striatus*	3395	3396	F			Y
08/01/01	AM	HB-02	*Tamias striatus*	3395	3396	F	92	N	Y
09/01/01	AM	F1-10	*Peromyscus maniculatus*	3467	3468	M	20	N	N
09/01/01	AM	F1-13	*Peromyscus maniculatus*	3499	3500	M	12	N	N
07/31/01	AM	F1-16	*Tamias striatus*	3875	3975	M	100	N	Y
05/29/01	AM	HA-2	*Clethrionomys gapperi*			M	23	N	N
05/29/01	PM	HA-48	*Tamisciurus hudsonicus*			M		Scrotal	N

Date	Time	Trap	Species	Tag	Sex	Mass (g)	Reproductive Condition	Recapture
05/30/01	AM	HA-73	*Tamisciurus hudsonicus*					Y
05/30/01	AM	HD-6	*Tamisciurus hudsonicus*					
05/30/01	AM	HA-60	*Tamisciurus hudsonicus*					
05/30/01	PM	HA-73	*Tamisciurus hudsonicus*		M	140	Scrotal	
05/30/01	PM	HD-05	*Tamisciurus hudsonicus*					
07/03/01	PM	HA-65	*Tamisciurus hudsonicus*					
07/04/01	AM	F2-05	*Clethrionomys gapperi*			20		Y
07/04/01	PM	HA-02	*Blarina brevicauda*			23		N
07/31/01	AM	HA-37	*Tamias striatus*		M	64	N	N
07/31/01	PM	HB-07	*Tamias striatus*					Y
07/31/01	PM	HA-02	*Sorex sp.*			3		
08/01/01	AM	HA-64	*Sorex sp.*			3		N
08/01/01	AM	F1-05	*Sorex sp.*			3		N
08/01/01	AM	F1-15	*Sorex sp.*			3		N
08/01/01	AM	F1-19	*Sorex sp.*			3		N
08/01/01	PM	HA-06	*Tamisciurus hudsonicus*			128		N
09/01/01	AM	HA-71	*Blarina brevicauda*			14		
09/01/01	AM	F3-23	*Peromyscus maniculatus*					N

Date	Time	Trap	Species	Tag	Sex	Mass (g)	Reproductive Condition	Recapture
09/01/01	PM	HB-12	*Blarina brevicauda*			18		N
09/01/01	PM	HA-06	*Tamisciurus hudsonicus*					
09/01/01	PM	HA-15	*Tamias striatus*			112		N
09/01/01	PM	F2-15	*Tamias striatus*		F	82	N	N
09/01/01	PM	F3-23	*Clethrionomys gapperi*		M	17	N	N
09/01/01	PM	HA-69	*Tamias striatus*		F	91	N	N

Table 4. Capture data for Site 4, Prince Edward Island National Park. Note that blank cells indicate the information was not available.

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/06/0	PM	F1-17	*Tamias striatus*						
06/06/0	PM	F4-11	*Tamias striatus*	2328	2763	F	89	Nipples	Y
06/07/0	PM	F4-17	*Tamias striatus*	2763	2328	F	80	Nipples	Y
06/07/0	PM	HB-17	*Tamias striatus*	1792	2997	M	101	Scrotal	Y
06/06/0	PM	F4-02	*Tamias striatus*	1978	2185	F	85	Nipples	Y
07/11/0	PM	F4-02	*Tamias striatus*	1978	2185	F	89	Nipples	Y
09/05/0	AM	HA-01	*Tamias striatus*	1978	2185	F	90	N	Y
08/08/0	AM	F1-18	*Tamias striatus*	2406	2407	M	104	N	N
06/07/0	PM	F4-05	*Tamias striatus*	2462	2463	M	80	Scrotal	Y
07/11/0	PM	F13-	*Tamias striatus*	2522	2523	F	90	Nipples	Y
07/12/0	PM	F13-	*Tamias striatus*	2522	2523	F	87	Nipples	Y
06/07/0	PM	F4-01	*Tamias striatus*	2527	2528	F	88	N	Y
06/07/0	PM	HC-10	*Tamias striatus*	2541	3095	M	81	Scrotal	Y
06/06/0	PM	F4-12	*Tamias striatus*	2587	2845	M	88	Scrotal	Y
06/07/0	PM	F4-11	*Tamias striatus*	2587	2845	M	84	Scrotal	Y
07/12/0	PM	F4-06	*Tamias striatus*	2587	3292	M	94	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
08/07/0	AM	F4-01	*Tamias striatus*	3292	2587	M	112	N	Y
06/06/0	PM	F4-20	*Tamias striatus*	2592	2842	M	95	Scrotal	Y
06/07/0	PM	F4-15	*Tamias striatus*	2842	2592	M	91	Scrotal	Y
06/06/0	PM	HB-02	*Tamias striatus*	2617	3070	M	100	Scrotal	Y
07/11/0	PM	HB-14	*Tamias striatus*	2617	2997	M	90	Scrotal	Y
09/05/0	AM	HB-12	*Tamias striatus*	2617	2997	M	98	N	Y
06/06/0	PM	HB-05	*Tamias striatus*	2634	3052	M	109	Scrotal	Y
06/07/0	PM	HC-14	*Tamias striatus*	2646	3050	M	73	Scrotal	Y
06/07/0	PM	F1-19	*Tamias striatus*	2741	2942	F	91	N	Y
06/06/0	PM	F4-25	*Clethrionomys gapperi*	2843	2927	M	17	Scrotal	N
06/07/0	PM	F4-20	*Clethrionomys gapperi*	2843	2927	M	18	Scrotal	Y
06/06/0	PM	HA-04	*Tamias striatus*	2844	2947	F	86	N	N
06/07/0	PM	HA-05	*Tamias striatus*	2844	3062	F	89	N	Y
06/06/0	PM	HA-01	*Tamias striatus*	2901	2928	M	92	Scrotal	N
06/07/0	PM	F4-02	*Tamias striatus*	2901	2928	M	86	Scrotal	Y
07/12/0	PM		*Tamias striatus*	2901	2928	M	88	Scrotal	Y
08/08/0	AM	HA-05	*Tamias striatus*	2901	2928	M	95	N	Y
06/06/0	PM	HA-35	*Tamias striatus*	2926	2930	M	84	N	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/06/0	PM	HA-02	*Tamias striatus*	2935	2946	F	84	Nipples	N
06/07/0	PM	HA-04	*Tamias striatus*	2935	2946	F	82		Y
07/11/0	PM	HA-04	*Tamias striatus*	2935	2946	F	90	Nipples	Y
07/12/0	AM	HA-10	*Tamias striatus*	2935	2946	F	109	Nipples	Y
06/06/0	PM	F1-02	*Tamias striatus*	2937		F	87	N	N
06/07/0	PM	F1-07	*Tamias striatus*	2937	3058	F	80	N	Y
07/11/0	AM	F1-02	*Tamias striatus*	3058	3199	F	85	N	Y
07/11/0	PM	HB-23	*Tamias striatus*	3058	3199	F	91	N	Y
07/12/0	AM	HB-06	*Tamias striatus*	3058	3199	F	88	N	Y
07/12/0	PM	HB-23	*Tamias striatus*	3058	3199	F	81	N	Y
06/06/0	PM	F1-20	*Tamias striatus*	2941	2962	M	88	N	N
07/11/0	PM	F1-12	*Tamias striatus*	2942	3158	F	95	N	Y
07/12/0	PM	F1-09	*Tamias striatus*	2942	3158	F	95	N	Y
08/01/0	PM	F1-18	*Tamias striatus*	3158	3214	F	96	N	Y
08/08/0	PM	F1-15	*Tamias striatus*	3158	3214	F	101		Y
09/05/0	PM	F1-19	*Tamias striatus*	3158	3214	F	105	N	Y
06/06/0	PM	HA-45	*Tamias striatus*	2943	2944	M	89	Scrotal	N
06/07/0	PM	HA-40	*Tamias striatus*	2943	2944	M	90	Scrotal	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/07/0	PM	F1-20	*Tamias striatus*	2995	2996	M	92	Scrotal	
06/06/0	PM	F4-08	*Tamias striatus*	2998	2999	F	71	N	N
09/05/0	PM	F4-13	*Tamias striatus*	3022		M	78	N	Y
06/06/0	PM	HA-12	*Tamiasciurus hudsonicus*	3026	3060	M	175	Scrotal	N
06/07/0	PM	F1-17	*Tamias striatus*	3027	3028	M	105	Scrotal	N
06/07/0	PM	F1-14	*Tamias striatus*	3047	3048	F	81	Nipples	N
06/07/0	PM	F13-	*Tamias striatus*	3049	3054	M	89	Scrotal	N
07/11/0	PM	F13-	*Tamias striatus*	3049	3177	M	97	Scrotal	Y
06/06/0	AM	HB-01	*Tamias striatus*	3051	3075	M	105	Scrotal	Y
06/07/0	PM	HC-18	*Tamias striatus*	3055	3096	M	90	Scrotal	N
06/07/0	PM	F4-25	*Tamias striatus*	3056	3057	F	94	Nipples	N
06/07/0	PM	HA-01	*Tamias striatus*	3059	3092	M	80	Scrotal	Y
06/07/0	AM	F12-	*Tamias striatus*	3064	3065	F	82	N	N
06/07/0	AM	F12-	*Tamias striatus*	3066	3067	F	80	N	N
06/06/0	PM	F1-11	*Tamias striatus*	3068	3069	F	114	Nipples	
06/07/0	PM	F1-13	*Tamias striatus*	3068	3069	F	104	Nipples	Y
06/06/0	PM	HB-03	*Tamiasciurus hudsonicus*	3071	3075	M	146	Scrotal	N
06/06/0	PM	HB-01	*Tamias striatus*	3072	3073	M	93	Scrotal	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
06/07/0	PM	HB-04	*Tamias striatus*	3072	3073	M	91	Scrotal	Y
07/11/0	PM	HB-02	*Tamias striatus*	3072	3157	M	89	Scrotal	Y
07/12/0	PM	HB-07	*Tamias striatus*	3072	3157	M	102	Scrotal	Y
09/05/0	PM	HB-05	*Tamias striatus*	3072		M	100	N	Y
06/07/0	PM	F1-16	*Tamias striatus*	3077	3078	M	94	Scrotal	N
07/12/0	PM	F1-04	*Tamias striatus*	3078	3283	M	85	Scrotal	Y
06/07/0	AM	F12-	*Peromyscus maniculatus*	3097	3098	M	20	Scrotal	N
08/07/0	AM	F12-	*Peromyscus maniculatus*	3098	3255	M	16	Scrotal	Y
06/07/0	AM	F12-	*Tamias striatus*	3099	3100	M	92	Scrotal	N
07/11/0	AM	HA-20	*Zapus hudsonius*	3156	3200	F	17	Nipples	N
07/11/0	PM	F1-17	*Tamias striatus*	3159	3160	F	87	Nipples	
07/11/0	PM	F1-07	*Tamias striatus*	3161	3162	M	94	Scrotal	Y
07/12/0	PM	F1-11	*Tamias striatus*	3161	3284	M	89	Scrotal	Y
07/11/0	PM	HB-21	*Tamias striatus*	3163	3164	M	95	Scrotal	N
07/11/0	PM	HA-09	*Tamias striatus*	3165	3179	F	73	N	N
07/11/0	PM	F4-18	*Tamias striatus*	3166	3189	M	60	N	N
07/12/0	PM	F4-18	*Tamias striatus*	3166	3189	M	65	N	Y
08/07/0	PM	F4-23	*Tamias striatus*	3166	3189	M	76		Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/11/0	PM	HC-04	*Tamias striatus*	3167	3168	F	71	N	N
07/11/0	PM	HC-02	*Tamias striatus*	3169	3171	M	86	Scrotal	Y
07/12/0	PM	F12-	*Tamias striatus*	3169	3171	M	89	Scrotal	Y
09/05/0	AM	F12-	*Tamias striatus*	3171	3203	M	89	N	Y
09/05/0	PM	F12-	*Tamias striatus*	3171	3203	M	88	N	Y
07/11/0		HA-42	*Tamias striatus*	3170		M	93	Scrotal	Y
07/11/0	AM	F12-	*Tamias striatus*	3172	3173	F	85	Nipples	Y
07/11/0	PM	F12-	*Tamias striatus*	3172	3173	F	86	Nipples	Y
07/12/0	PM	F12-	*Tamias striatus*	3172	3173	F	85	N	Y
08/07/0	PM	F12-	*Tamias striatus*	3172	3204	F	81	Nipples	Y
08/08/0	PM	F12-	*Tamias striatus*	3172	3204	F	82	Nipples	Y
09/05/0	PM	HC-03	*Tamias striatus*	3172	3204	F	81	N	Y
07/11/0	AM	F12-	*Tamias striatus*	3174	3193	F	89	N	N
07/11/0	PM	F13-	*Tamias striatus*	3178	3181	M	87	Scrotal	N
07/11/0	PM	F13-	*Tamias striatus*	3182	3196	F	86	N	N
07/12/0	PM	F13-	*Tamias striatus*	3182	3196	F	84	N	Y
07/11/0	PM	F4-08	*Tamias striatus*	3183	3184	M	84	N	N
07/12/0	PM	F4-14	*Tamias striatus*	3183	3184	M	87	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/11/0	PM	HB-07	*Tamias striatus*	3185	3186	F	68	N	N
07/12/0	PM	HB-10	*Tamias striatus*	3185	3186	M	51	N	Y
07/11/0	PM	F1-01	*Tamias striatus*	3187	3188	M	82	Scrotal	
07/12/0	PM	F1-07	*Tamias striatus*	3187	3188	M	80	Scrotal	Y
08/07/0	PM	F1-08	*Tamias striatus*	3187	3188	M			Y
09/05/0	AM	F1-05	*Tamias striatus*	3187	3188	M	91	N	Y
07/11/0	PM	F4-09	*Tamias striatus*	3190	3191	F	64	N	N
08/07/0	PM	F4-05	*Tamias striatus*	3191	3211	F	83	N	Y
07/11/0	AM	HC-02	*Peromyscus maniculatus*	3194	3195	M	20	Scrotal	N
07/11/0	PM	F13-	*Tamias striatus*	3197	3198	F	82	N	N
07/12/0	PM	F13-	*Tamias striatus*	3197	3198	F	90	N	Y
08/07/0	AM	HA-38	*Tamias striatus*	3201	3202	M	96	N	N
08/07/0	PM	HA-38	*Tamias striatus*	3201	3202	M	93		Y
08/08/0	PM	HA-36	*Tamias striatus*	3201	3202	M	87	N	Y
09/05/0	PM	HA-45	*Tamias striatus*	3202		M	94	N	Y
08/07/0	PM	F12-	*Tamias striatus*	3205	3206	F	91	Nipples	N
08/07/0	PM	HC-10	*Tamias striatus*	3207	3208	F	79	N	Y
08/08/0	PM	HC-10	*Tamias striatus*	3207	3208	F	76	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
09/05/0	AM	HC-11	*Tamias striatus*	3207	3308	F	76	N	Y
09/05/0	PM	HC-14	*Tamias striatus*	3207	3208	F			Y
08/07/0	PM	F13-	*Tamias striatus*	3209	3210	F	73	N	N
08/08/0	PM	F13-	*Tamias striatus*	3209	3210	F	73		Y
08/07/0	PM	F4-08	*Tamias striatus*	3212	3213	F	82	N	N
09/05/0	AM	F4-08	*Tamias striatus*	3212	3213	F	81	N	Y
09/05/0	PM	F4-08	*Tamias striatus*	3212	3213	F	77	N	Y
08/08/0	AM	HC-19	*Peromyscus maniculatus*	3215	3216	M	11	N	N
08/08/0	AM	F12-	*Napaeozapus hudsonius*	3217	3218	M	25	Scrotal	N
08/08/0	AM	F12-	*Peromyscus maniculatus*	3219	3220	M	17	Scrotal	
08/08/0	AM	F12-	*Peromyscus maniculatus*	3221	3222	M	20	Scrotal	N
07/12/0	AM	HA-25	*Mustela erminea*	3223	3297	F	73	N	N
07/11/0	PM	HA-43	*Tamias striatus*	3224	3225	F	64	N	N
07/12/0	PM	F4-13	*Tamias striatus*	3251	3293	M	68	N	N
07/12/0	PM	F4-20	*Tamias striatus*	3252	3282	M	91	Scrotal	Y
08/07/0	AM	F12-	*Peromyscus maniculatus*	3256	3257	M	13	N	N
08/07/0	AM	HC-19	*Peromyscus maniculatus*	3258	3259	F	17	N	Y
09/05/0	AM	F13-	*Peromyscus maniculatus*	3259		M	16	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
08/07/0	AM	HB-03	*Tamias striatus*	3260	3261	M	88	N	N
08/08/0	AM	HA-12	*Tamias striatus*	3260	3261	M	90		Y
08/07/0	AM	HA-13	*Tamias striatus*	3262	3263	M	95	N	N
08/08/0	AM	HA-14	*Tamias striatus*	3262	3263	F	84	N	Y
08/08/0	PM	HA-12	*Tamias striatus*	3262	3263				
08/07/0	AM	F1-08	*Tamias striatus*	3267	3284	M	100	N	Y
07/12/0	PM	F12-	*Tamias striatus*	3274	3288	F	66	N	
08/07/0	AM	F12-	*Tamias striatus*	3274	3288	F	81	N	Y
08/07/0	PM	F12-	*Tamias striatus*	3274	3288	F	78		Y
08/08/0	AM	F12-	*Tamias striatus*	3274	3288	F			
08/08/0	PM	F12-	*Tamias striatus*	3274	3288	F	76	N	Y
09/05/0	AM	F12-	*Tamias striatus*	3274	3288	F	84	N	Y
09/05/0	PM	F12-	*Tamias striatus*	3274	3288	F	79	N	Y
07/12/0	PM	F13-	*Tamias striatus*	3275	3294	M	85	N	N
07/11/0	AM	HC-14	*Peromyscus maniculatus*	3276	3277	M	16	Scrotal	N
07/12/0	AM	HB-10	*Peromyscus maniculatus*	3278	3298	M	20	Scrotal	N
07/12/0	AM	HA-37	*Zapus hudsonius*	3279	3297	M	18	Scrotal	N
07/12/0	PM	HC-07	*Tamias striatus*	3280	3281	F	55	N	

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
07/12/0	PM	HB-20	*Tamias striatus*	3285	3286	F	72	N	N
07/12/0	PM	HC-03	*Tamias striatus*	3295	3296	F	65	N	N
07/11/0	AM	F13-	*Peromyscus maniculatus*	3297	3300	M	18	Scrotal	N
08/08/0	AM	F13-	*Peromyscus maniculatus*	3330	3405	M	13	Scrotal	Y
08/08/0	AM	F13-	*Tamias striatus*	3401	3402	M	87	N	N
09/05/0	PM	F13-	*Tamias striatus*	3402		M	87	N	Y
08/08/0	AM	F13-	*Peromyscus maniculatus*	3403	3404	M	8	N	N
08/08/0	AM	F4-24	*Peromyscus maniculatus*	3408	3409	M	18	N	N
08/08/0	AM	F1-14	*Tamias striatus*	3410	3411	M	80	N	N
08/08/0	PM	F1-14	*Tamias striatus*	3410	3411	M	73	N	Y
09/05/0	AM	F1-09	*Tamias striatus*	3410	3411	M	79	N	Y
08/08/0	AM	F1-09	*Napaeozapus hudsonius*	3412	3413	F	24	Y	N
08/08/0	PM	F13-	*Tamias striatus*	3414	3415	M	81	N	N
08/08/0	PM	HC-07	*Tamias striatus*	3416	3417	F	78	N	Y
09/05/0	PM	F12-	*Tamias striatus*	3416	3417	F	82	N	Y
09/05/0	AM	F12-	*Peromyscus maniculatus*	3416	3480	M	11	N	N
08/01/0	PM	HC-19	*Tamias striatus*	3418	3419	F	67	N	N
08/08/0	PM	HB-19	*Tamias striatus*	3420	3421	M	95	N	Y

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
09/05/0	AM	F12-	*Glaucomys sabrinus*	3482	3497	F	87	N	N
09/05/0	AM	F12-	*Peromyscus maniculatus*	3483	3484	F	15	N	N
09/05/0	AM	F13-	*Peromyscus maniculatus*	3485	3486	M	13	N	N
09/05/0	AM	F13-	*Peromyscus maniculatus*	3487	3488	M	16	N	N
09/05/0	AM	F13-	*Peromyscus maniculatus*	3490	3491	F	14	N	N
09/05/0	AM	HC-06	*Peromyscus maniculatus*	3492	3493	M	13	N	N
09/05/0	AM	F12-	*Peromyscus maniculatus*	3494	3495	M	12	N	N
07/11/0	PM	HA-28	*Mustela erminea*	3699	3700	M	124	N	N
07/12/0	PM	HA-29	*Mustela erminea*						Y
08/07/0	PM	HB-17	*Tamias striatus*	3739	3740	M	77	N	N
08/07/0	PM	HA-26	*Tamias striatus*	3741	3742	M	88	N	N
08/08/0	PM	HA-21	*Tamias striatus*	3741	3742	M	92	N	Y
08/08/0	AM	HA-27	*Mustela erminea*	3749	3750	F	73		
08/08/0	PM	HA-39	*Tamias striatus*	3782	3783		76		N
08/08/0	PM	HA-27	*Mustela erminea*	3784	3785	M	151	Scrotal	N
09/05/0	AM	F1-02	*Peromyscus maniculatus*	4001		M	19	N	Y
09/05/0	AM	HB-22	*Peromyscus maniculatus*	4003	4004	M	17	N	N
09/05/0	AM	HB-21	*Napaeozapus hudsonius*	4005	4006	M	19	N	N

Date	Time	Trap	Species	Tag #		Sex	Mass (g)	Reproductive Condition	Recapture
09/05/0	AM	HA-34	*Tamias striatus*	4007	4024	M	81	N	N
09/05/0	AM	HB-18	*Tamias striatus*	4008	4009	M	75	N	N
09/05/0	AM	HB-14	*Napaeozapus hudsonius*	4010	4011	F	25	Nipples	N
09/05/0	AM	HB-13	*Peromyscus maniculatus*	4013		M	14	N	Y
09/05/0	AM	HA-24	*Zapus hudsonius*	4015	4020	F	23	N	N
09/05/0	AM	F1-11	*Peromyscus maniculatus*	4023	4025	M	11	N	N
06/06/0	AM	HB-22	*Tamias striatus*			M		Scrotal	N
06/06/0	AM	HB-23	*Tamias striatus*						
06/06/0	PM	HC-15	*Tamias striatus*			M	70	Scrotal	N
07/11/0	AM	HC-11	*Peromyscus maniculatus*				20		
07/11/0	PM	F1-04	*Tamias striatus*						N
08/07/0	AM	HB-23	*Peromyscus maniculatus*			M	17	Scrotal	N
08/07/0	PM	F12-	*Blarina brevicauda*				19		N
08/07/0	PM	HB-20	*Tamias striatus*			M	87	Scrotal	Y
09/05/0	PM	HB-22	*Tamias striatus*			M	84	N	N
09/05/0	PM	HA-08	*Tamias striatus*			M	76	N	N
09/05/0	PM	HC-10	*Tamias striatus*			M	74	N	N
09/05/0	PM	HB-03	*Tamias striatus*			F	90	N	N

Date	Time	Trap	Species	Tag #	Sex	Mass (g)	Reproductive Condition	Recapture
09/05/0	PM	HA-30	*Sorex sp*			3		N
09/05/0	PM	F4-24	*Sorex sp*			3		
09/05/0	PM	F4-20	*Sorex sp*			3		
06/06/0	PM	HC-15	*Tamias striatus*		M	70	Scrotal	N
06/06/0	PM	HC-03	*Tamias striatus*					
06/06/0	PM	F13-	*Tamias striatus*					
06/06/0	PM	F13-	*Tamias striatus*					
06/07/0	PM	F4-22	*Glaucomys sabrinus*					
07/12/0	AM	HA-04	*Mustela erminea*					
09/05/0	PM	F1-01	*Tamias striatus*					