

The role of interspecific interactions between the hispid cotton rat, *Sigmodon hispidus*
and the marsh rice rat, *Oryzomys palustris*

INTRODUCTION

Ecological communities are composed of organisms within a complex system that are influenced by various abiotic and biotic features and interactions with other organisms. Such complex structure has compelled biologists to search for an explanation to aid in understanding the patterns of species distribution and abundance within these complex communities. These processes are influenced by the ability to tolerate changes in the environment, the availability of essential resources, and interactions with related and unrelated species. In order to explain how species are distributed throughout a particular habitat, ecologists must understand what role species' interactions play within the community. Determining the effects of different types of interactions among the community's populations will ultimately allow us to interpret the consequences of such interactions.

Interspecific Interactions

Over the years, understanding the effects of interspecific interactions has become a means of explaining community structure and an important part of community ecology (Dayan and Simberloff 1998). Interspecific interactions are those interactions occurring between different species. The different types of interactions are competition, predation and parasitism, mutualism, commensalism, and ammensalism. Interspecific interactions are important to the community because they help quantify population sizes for K-selected species that generally experience density dependent forces (Morin 1999). Being

able to interpret how these effects will influence species abundances will allow ecologists to interpret and predict how a population will respond to the presence of other species within the community.

Among the types of interactions mentioned above, competitive interactions are the most widely studied and the most difficult to prove (Perri and Randall 1999). Community ecologists must recognize that temporally, behaviorally, or socially mediated mechanisms could be influencing abundance and habitat use. Despite this possibility, interspecific competition has been regarded as the causal basis for structured resource partitioning present in many communities (Koplin 1968, Williams 1969, Case and Bolger 1991, Losos 1994). Providing evidence for changes in abundance and habitat use based on how resources are utilized.

Habitat Partitioning

Habitat partitioning is the most common mode of resource partitioning in sympatric species (Schoener 1974). Analyzations of habitat use ask how much overlap in resources can be permitted if both species are to coexist (MacArthur and Levins 1967). More specifically, how should a number of species partition a given number of resources to maximize their fitness? Understanding these questions is important because habitat partitioning is one mechanism that allows species to coexist in a given habitat. It provides valuable information on species' distribution as a function of intra- and interspecific densities and is effective in maintaining the diversity of the ecological community. Rosenzweig (1979) hypothesized that interspecific competition may reinforce the tendency for species to partition their habitat and serve to stabilize the relationship

between species. Studies on birds (Post 1981), insects (Brown 2001), and fish (Jakober et al. 2000) have shown that interspecific competition causes species to partition their habitat. However, studies investigating resource use and competitive interactions, suggests that the importance of interspecific competition in small mammal communities is highly variable.

The role of microhabitat partitioning in determining rodent habitat associations has been well studied (Price 1978, Brown et al. 1979, Morris 1987, Jorgensen and Demarais 1999). Some studies have attempted to demonstrate that interspecific competition is responsible for observed difference in resource use, but among these studies only a few provide evidence supporting these claims (Koplin and Hoffmann 1968, Grant 1969, Morris and Grant 1972, Petersen 1973, Kincaid et al. 1983, Frank and Layne 1992, Lozada et al. 2000). Others such as, M'Closkey and Fieldwick (1975), Schroder and Rosenzweig (1975), Cameron (1977), Krebs (1977), Smith (1980), and Haering and Fox (1995) have found no evidence supporting hypotheses that differences in resource use were due to competition. Most of the empirical evidence supporting competitive effects are comparisons of allopatric and sympatric species distributions (Strong et al. 1979, Schoener 1982). However, poorly implemented experiments and disregard for alternative explanations have led to criticisms of competitively based explanations of community structure.

Alternative mechanisms

One should not rule out the possibility that species distribution patterns could be caused by intraspecific and interspecific behaviors (Putera and Grant 1985, Perri and Randall 1999, Shanker 2001), predation-disturbance factors (Paine 1966), environmental

variability (Weins and Rotenberri 1981, Adler and Wilson 1987, Abrams 2000), or habitat preference (Goldingay and Price 1997, Rossell and Rossell 1999). Organisms share and compete for food and space and it is important to understand how these resources are partitioned when species have overlapping resources. If densities are high for both species, then available resources will be depleted at a faster rate than if only one species were present. Therefore, species with overlapping resources must partition them so that both can use them (Schoener 1989). Studies suggest that species avoid competition via habitat partitioning (Schroder and Rosenzweig 1975, Morris 1996, Leal 1998, Busch and Kravetz 1992), however there must be evidence of interspecific interactions before such conclusions can be made. Interspecific interactions are strongest when resources overlap between the species.

Determining interactions

Interspecific interactions occur if the presence of one species causes the other species to: 1) alter patterns of habitat or resource use; 2) experience changes in abundance that reflect differences in individual fitness; 3) exhibit changes in survival rates; or 4) experience changes in population growth rate (Grant 1972). There are two forms of evidence for interspecific interactions of sympatric species: 1) two sympatric species exhibit an inverse numerical relationship, and 2) sympatric species exhibit an inverse spatial relationship (Grant 1972). In the first situation, population parameters, such as abundance, survival, and sex ratio may reflect the outcome of competitive interactions in temporarily varying environments (Brower and Cade 1966, Shure 1970, Tamarin and Malecha 1971) because two similar species cannot utilize the same resources without one eventually drifting to extinction. In the second situation the two

species occupy different parts of the same habitat as a result of interspecific competition rather than variations in habitat features (Batzli 1968, Baker 1971). Many factors may come into play when interspecific interactions are in question, however controlled and replicated experimental manipulations will help to determine what independent factors are influencing the species resource use and abundance.

Experimental manipulations

Experimental data on habitat use by rodents (Crowell and Pimm 1976, Bowers et al., 1987, Harney and Dueser 1987, Scott and Dueser 1992) has shown that small mammal communities are shaped by intra and interspecific competition (Batzli 1985). Within these communities they usually partition the habitat in order to separate themselves from other sympatric species (Schoener 1974, Harney and Dueser 1987, Thompson and Fox 1993). Rosenzweig (1979) determined that interspecific competition reinforced the tendency for habitat allocation and helped to stabilize coexistence between species. Bilenca and Kravetz (1999) discovered two rodent species in Argentina segregating their habitat use in overlapping regions, with the dominant of the two retaining the more suitable habitat.

The effects of interspecific interactions upon habitat use and population dynamics of sympatric and allopatric species may be determined experimentally in the field by species removal studies (Connell 1975, Pianka 1976, Cameron 1977, Leal et al. 1998). This approach has been successful in testing for competitive effects in a variety of taxa; including marine invertebrates (Connell 1961, Dayton 1971), fish (Werner and Hall 1977, Larson 1980), amphibians and reptiles (Jaeger 1971, Dunham 1980, Keen 1982, Dial and Roughgarden 1995), birds (Martin and Martin 2001), and mammals (Grant 1969, Joule

and Jameson 1972, Schroder and Rosenzweig 1975, Price 1978, Abramsky et al. 1990, Perri and Randall 1999). Manipulative experiments are important tools for testing for competitive effects because they help to ensure that treatment effects are not confounded by extraneous environmental factors. When conducted properly, these controlled and replicated experiments offer the best hope for detecting interspecific competition within a community (Hairston 1984).

Despite the numerous studies, not all competitive systems are susceptible to field manipulations. In order to understand how interspecific interactions influence a community, the system must include species whose densities can be substantially altered by the investigator. Species that preferably, have low vagility or the potential to influence immigration/emigration. In addition, vital resources must be in short supply in a relatively young community in which mechanisms of coexistence have yet to develop (Skalski and Robson 1992). Several studies meeting these criteria have been performed on small mammals because they are generally abundant in a variety of habitats where they can be manipulated quite easily. Among these interaction studies, the hispid cotton rat (*Sigmodon hispidus*) has been investigated quite frequently because of its ability to interact and coexist with a number of rodent species throughout its geographical range. Martin (1956) determined that interspecific competition was responsible for declines in *M. ochrogaster* abundance as dispersing *S. hispidus* entered regions in central Kansas. Years later, Frydendall (1969) discovered that the decline of *S. hispidus* caused *M. ochrogaster* to migrate from less suitable peripheral habitat back into the more suitable grassland habitat. These results indicate that *S. hispidus* may have forced *M. ochrogaster* into a sink habitat system.

Sigmodon hispidus was also studied in Texas to determine its effects on other sympatric species in a grassy habitat. In this study Joule and Jameson (1972) found that removing *S. hispidus* from a shared habitat, did not change the mean weight of *O. palustris* or *Reithrodontomys fulvescens*. In addition, there was no significant effect on the abundance of *R. fulvescens*, and a negligible effect on the abundance of *O. palustris*. Removal of *O. palustris* and *R. fulvescens* had no effect on *S. hispidus* abundance, however there was a significant change in mean body weight and sex ratio. Competitive effects were not concluded in this study, but there is evidence that some of these species are interacting and influencing one another.

Kincaid et al. (1983) discovered some habitat overlap between *S. hispidus* and *O. palustris*, but observed the two species utilizing the habitat differently during all four seasons. *Sigmodon hispidus* predominately occupied grassy habitats dominated by *Spartina sp.*, while *O. palustris* was present in habitats dominated by dicots such as *Ampelopsis*. This study is useful in understanding how interspecific interactions influence sympatric species in a community because it describes how a common resource can be partitioned by both species. However, this study fails to provide empirical data to support any additional claims. Many studies concentrating on interspecific interactions among *S. hispidus* and its sympatric species have lacked the empirical data and/or proper experimental design to adequately answer such questions. In addition, there are some areas where so few studies have been performed that it is difficult to generalize how a species, such as *S. hispidus*, influences other species in its community. For example, *S. hispidus* and *O. palustris* range throughout the southeastern and south-central U.S.,

however only a small number of species interaction studies have ever been performed in South Florida.

Studies in South Florida

Some of these studies focus on the effects of interspecific interactions on coexisting rodent species in sympatric situations, while the others provide useful information on how the species utilize their habitat. Smith and Vrieze (1979) detected *S. hispidus* and *O. palustris* utilizing habitat differently in each season on the hammock islands in the Florida Everglades. During the dry season *S. hispidus* used both the hammock and surrounding prairie habitats at a much greater frequency than *O. palustris*, which seemed to disappear from the system altogether. During the wet season *S. hispidus* and *O. palustris* used the hammock islands more often than *Oryzomys*, but the reverse was true in the following year because of predation on the *Sigmodon* population.

Smith (1980) analyzed interaction effects present in the Everglades in a follow-up study. He found no evidence of an increase in the population size of one species negatively affecting the other. Thereby concluding that the distribution of one species was independent of the other and no competition was occurring. This data provides a framework for such studies in the Florida Everglades because it was the first of its kind. However lack of adequate sample sizes and weak statistical analysis fail to provide strong support for Smith's conclusions.

A long-term study on patch dynamics of tree island size in the Florida Everglades discovered that *S. hispidus* had the highest densities and reproductive activity on large islands, while *O. palustris* had the highest densities on the small islands (Gaines in press).

Medium sized islands were occupied by both species at similar densities. Additional habitat use data was recently analyzed in the same system, however the results are yet to be published. These results showed that there was a negative spatial relationship between *S. hispidus* and *O. palustris* in the Florida Everglades hammock island system. During the dry season, *S. hispidus* had significantly greater percent capture rates than *O. palustris* on the medium and large sized islands. On the medium sized island *S. hispidus* occupied the internal portion of the island more often than *O. palustris*. However, there was no significant difference between capture rates of both species on the edges of the island. On the large island *S. hispidus* utilized the internal and edge portions of the island more frequently than *O. palustris*.

The opposite occurred during the wet season, with *O. palustris* having greater percent capture rates than *S. hispidus* on the medium and large islands. On both of these islands, *O. palustris* utilized the internal and edge portions of the habitat more frequently than *S. hispidus*. The traps on these islands were randomly distributed throughout the edge and internal portions of the islands. However, more accurate conclusions could be made if the traps were placed in a grid system encompassing the edge and internal portions of the island as well as the surrounding prairie habitat. These two sympatric species show a differential spatial distribution between tree island habitat and its borders in this system. This spatial distribution could possibly be attributed to habitat segregation due to species interactions or simply due to seasonal changes in hydrology. Internal habitats would appear to be more suitable for the rodent species because they provide more habitat for nesting and foraging and offer more plant cover than the edge of the

island. Therefore, species diversity, changes in water levels, and high population sizes on these islands may enhance competition for space within this habitat.

To understand patterns of species' distribution and abundance, it is important to discern if and how species are influencing one another in sympatric situations. It is evident by the limited number of studies that more could be known about these species and how they affect one another in the Florida Everglades ecosystem. Therefore, the goal of this project is to assess the role of interspecific interactions in determining spatial distributions and relative abundances of *Sigmodon hispidus* and *Oryzomys palustris* in the Florida Everglades. Specifically, addressing whether the spatial relationship between the two species and changes in population dynamics are due to such interactions. Reciprocal-removal experiments will be conducted to test for the occurrence and consequences of interspecific interactions between the two rodent species on several hammock tree islands in the Florida Everglades.

BACKGROUND

The study will be conducted within the Everglades National Park (N 25° 24' 05.1", W 80° 37' 59.3"). The Everglades experiences a dry season (Nov.-April) and a wet season (May-Oct.). With annual rainfall typically ranging from 117.0 mm $\pm$ 17.96 (EREC 2001) and temperatures ranging from 7.2 to 32.4° C. Within the Everglades' mosaic of habitats, the hardwood hammock islands are one of the highest, driest habitats, but they are surrounded by a prairie habitat that frequently becomes inundated. The Everglades National Park provides a unique opportunity to study the hispid cotton rat and the marsh rice rat because it is a Federally protected area composed of large portions of habitat specific to these species. Both *S. hispidus* and *O. palustris* have been observed in the

hammock tree island habitat as well as in the surrounding habitat. The hardwood hammocks are comprised of broad-leaved evergreen species that provide an adequate amount of cover in the form of a dense upper canopy (Gunderson 1994).

Small mammal populations persist in a unique situation in the tree island habitat of the Florida Everglades. These islands are characterized as either bay heads or hardwood hammocks (Gunderson 1994), which are scattered throughout a seasonally flooded prairie habitat. The tree islands vary in size and are dominated by sweet bay (*Magnolia virginiana*), red bay (*Persea borbonia*), dahoon holly (*Ilex cassine*), poisonwood (*Metopium micrantha*), wax myrtle (*Myrica cerifera*), and wild coffee (*Psychotria nervosa*). The surrounding prairie is composed of muhly grass (*Muhlenbergia filipes*) and sawgrass (*Cladium jamaicense*). Hence, the tree island system provides two interesting contrasts in which to compare. These islands are essential to the Everglades ecosystem because they provide food resources such as seeds, fruits, and insects that cannot be found in the prairie matrix (Gaines in press.), dry ground for nest sites, and a dense understory for protection from predators. The prairie/hammock habitat provides a wonderful opportunity to investigate the effects of interspecific interactions of sympatric species because there is a possibility that both species may be utilizing and selecting habitat depictive of source-sink models.

Sigmodon hispidus and *O. palustris* are two of the co-dominant rodents that inhabit the Florida Everglades (Smith 1980). They were selected for this study because they have somewhat similar morphology, size, food preferences, and overlapping mean home ranges of about 0.38 ha. for males and 0.24 ha. for females. It was therefore

supposed that *S. hispidus* and *O. palustris* would likely be the strongest competitors of three sympatric species in this habitat.

Sigmodon hispidus, also known as the hispid cotton rat, is one of the most common rodents of the southern United States. They inhabit dry habitats such as flatwoods, scrub (Layne 1974), and grassland habitats (Fleharty and Mares 1973). With a range extending west to Kansas and Nebraska, further south to southern New Mexico and southeastern Arizona, and from Florida north to Virginia on the eastern coast (Cameron and Spencer 1981). Internationally they extend northward from northern South America through Central America and Mexico (Kiblicky 1969). Average home ranges are 0.39 ha for adult males and 0.22 ha for females (Fleharty and Mares 1973), with females maintaining exclusive home ranges. *Sigmodon hispidus* is bimodally nocturnal, active in the early evening and somewhat active in the late evening (Calhoun 1945, Kilduff and Dube 1979). The cotton rat is distinguishable by its dark brown and sparsely gray hair colored pelage. Adult body weights range from 110 to 225 g. for males and 100 to 200 g. for females (Chipman 1965). Sexual maturity in males can be determined by the presence of descended testes and generally occurs 30 days after birth (~ 60g) (Chipman 1965). While female sexual maturity can be determined by the presence of an open vagina, swollen nipples, and an open pubic symphysis. This generally occurs 30 – 40 days after birth (~ 60 to 80 g) (Meyer and Meyer 1944) with a gestation period of about 27 days. Their diet consists mainly of grasses and seeds (Fleharty and Olson 1969), however occasionally they feed on insects (Svihla 1929) and bird eggs (Meyer and Meyer 1944).

Oryzomys palustris, also known as the marsh rice rat, is semi-aquatic and inhabits mesic habitats such as hydric hammocks, swamps and freshwater marshes and meadows

(Goertz and Long 1973). Geographically, it extends from southeastern Pennsylvania and southern New Jersey southward to the tip of Florida and westward to eastern Texas (Hall 1981). Negas et al. (1961) determined an average home range of 0.37 ha. for males and 0.23 ha. for females. However, in Florida Birkenholz (1963) found the average home range to be 0.25 ha. and 0.33 ha. for males and females respectively. *Oryzomys palustris* is primarily nocturnal (Kilduff and Dube 1979) and is distinguishable by its grayish brown pelt and white under body. Adult body weights range from 45 to 80 g. for both males and females (Wolfe 1982). Sexual maturity in males and females is determined by the same characteristics listed for *S. hispidus*. However, both male and female *Oryzomys* become sexually mature after 50 to 60 days of age (Conaway 1954, Svihla 1931). The diet of *O. palustris* is somewhat broader than that of *S. hispidus*. It includes a small amount of seeds and plants (Hamilton and Whitaker 1979, Lowery 1974), but mainly consists of insects, fish, and arthropods because *O. palustris* are predominantly carnivorous. However, *O. palustris* occasionally forages for food common to the *Sigmodon*'s diet during the dry season (Negas et al. 1961).

It is evident that these two rodent species are relatively distinct from one another, but they do have some similarities and often overlap in their use of resources. Therefore, there is the potential for strong interactive effects between *S. hispidus* and *O. palustris*. The potential for competition exists in most ecological situations, but social interactions must be considered before any definite conclusions can be made. Christensen (1980) performed a behavioral study on the interactions of *S. hispidus* and *O. palustris* and discovered that *O. palustris* was typically more aggressive and active than *S. hispidus*. However, there was no significant attack or dominance behavior detected between the

two species although attack behaviors did occur from both species. Ultimately, Christensen concluded that there was no interspecific competition present between these two species. The fact that attack behaviors were displayed by both species may indicate that some competition is occurring, but Christensen's sample size ($N = 20$) was not large enough to detect any significance. Therefore, further studies should be conducted to confirm or refute his conclusions.

In addition to social behaviors, environmental conditions may also play an important role considering interactions between sympatric species. Because the Everglades is a water driven system, it is also possible that differences in the habitat use and population dynamics (density, survivorship, and body mass) are more influenced by changes in water levels rather than interspecific interactions. As mentioned earlier, *S. hispidus* tends to prefer dryer habitats, while *O. palustris* prefers wetter habitats. Therefore, both species may be partitioning habitats and dispersing to more suitable tree islands based upon seasonal changes in water levels. Water depths and hydroperiods influence growth, survival and where small mammals forage and nest by affecting the amount and availability resources. Long periods of inundation restrict the movement between islands for *S. hispidus* and decrease the available resources in the hammock island and prairie habitats. These environmental changes may cause individuals to become concentrated in large densities on the island, and increase competition for food, both intra- and interspecifically. This study will not address the foraging and nesting behaviors of these two species, but trapping data will help to determine how the habitat is being used and at what proportion.

The objective of this study is to explain and understand patterns of species distribution and abundance in rodents by examining interactions between sympatric species. I will examine the effects of reciprocal species removals on habitat use, abundance, survival, body mass, and sex ratio for each species. The following hypotheses will be tested by experimentally manipulating the population densities of both *Sigmodon hispidus* and *Oryzomys palustris*.

HYPOTHESES AND PREDICTIONS

Hypothesis 1 – If interspecific interactions are occurring, removal of the sympatric species should cause the remaining species to shift its structural habitat use into the area previously occupied by the removed species. The remaining species will occur in the other species' region more frequently in the absence than in the presence of the other species when comparing the experimental islands to the control islands.

Prediction 1 – Based on recent data addressing the habitat use of *S. hispidus* and *O. palustris* on two regions of the hammock island, removing *O. palustris* should cause *S. hispidus* to expand its habitat use to encompass the interior and edge regions of the island as well as the surrounding prairie in order to increase the number of potential resources.

Prediction 2 - I predict that removing *S. hispidus* from a shared hammock island will cause *O. palustris* to shift its distribution from the island edges to the interior in order to utilize available resources, such as nesting sites, food, and space more efficiently.

Prediction 3a – As water levels rise, *S. hispidus* will be more concentrated in the interior region of the *Oryzomys* removal islands because it is less mobile in wet conditions and suitable food and nest resources will become more limited due to the flooding of the prairie and island edge. Without the presence of the co-existing species, more *Sigmodons* can invade the interior regions of the islands, thereby increasing the number of capture rates. However, there will be a decrease in the number of individuals captured along the edge and in the prairie as a result of this.

Prediction 3b – As water levels increase, *O. palustris* will utilize the entire *Sigmodon* removal island, shifting its habitat use to the interior and edge portions of the island and the prairie in the absence of the co-existing species.

Predominately a more mesic species, *O. palustris* is not inhibited by standing water levels and can readily utilize all portions of the habitat as resources become more and more limited due to the inundation of the hammock island/prairie habitat. Therefore, capture rates will be greater on the removal islands than on the control islands.

Hypothesis 2 – If interspecific interactions influence both *S. hispidus* and *O. palustris*, the removal of one species will cause an increase in the density, survivorship, and mean body mass of the remaining species on the removal island when compared to the control islands.

Prediction 1 – The population density of the remaining species will increase as the density of the removed species decreases. This is possible because

the emigration of one sympatric species increases the possibility of other individuals from adjacent islands to invade the habitat because there are fewer individuals utilizing the perturbed habitat. As a result, both species will have greater capture rates than those individuals in the control islands in the absence of the co-existing species.

Prediction 2 – When the coexisting species is removed, the remaining species will have higher survival rates on the removal islands than on the control islands. The removal of one species will create more available space for cover, foraging, and nesting areas for the remaining species, thereby increasing the survival rate for the remaining species.

Prediction 3 – When the coexisting species is removed, the remaining species will have a higher mean body mass on the removal islands than on the control islands. *Sigmodon hispidus* and *O. palustris* differ in their diets, however *O. palustris* occasionally forages for food common to the *Sigmodon*'s diet during the dry season. If interspecific interactions are occurring, the absence of *O. palustris* will cause *S. hispidus* to have a greater increase in mean body mass compared to the control plots as males moving from non-*Sigmodon* removal islands invade the *Oryzomys* removal islands. Eventually, the mean body mass will climax when the population density reaches a level in which the *Sigmodons* are competing for resources. One would not expect to see deviations in the mean body mass of *O. palustris* between the removal and control islands because rice rats utilize a variety of food resources irrespective of *Sigmodon* feeding habits. Therefore, the overlap in their diets should have little effect on *O. palustris*.

METHODS

I will live trap both *Oryzomys palustris* and *Sigmodon hispidus* in six medium-sized hammock islands near Rock Reef Pass in the Everglades National Park on an 8 m x 8 m grid. Hammock islands will be selected based on the observed presence of similar vegetation, approximately equal area, and the presence of cotton and rice rats. The animals will be sampled every two weeks so that I can continually relocate cotton rats across the road to ensure that they are out of the experimental area. Vegetation at each station will be photographed to determine characteristics such as: type, height, diameter, and understorey cover. In addition, water levels will be measured with a meter stick around the edge of each island to determine if there are any possible correlations between water levels and the population dynamics of both rodent species. Approximately 200 Sherman traps (7.6cm x 7.6cm x 33cm) will be baited with crimped oats, set in the morning, and checked the following morning for four consecutive days. Cotton rats and rice rats caught on removal islands will be tagged, sexed, and weighed, placed in a partitioned box and relocated from their original trapping location in the Rock Reef Pass hammock area to a similar hammock habitat across the road that exceeds the rodents' home range (~ 65 m). Those caught on control islands will be released after data is taken. This density manipulation will allow me to monitor how both rodent species respond in areas without their sympatric counterparts, while still keeping them in their natural habitats.

DATA ANALYSIS

Population estimates will be determined using a mark-recapture technique for open populations (Jolly 1965) because both rodent populations are subject to immigration and emigration, recruitment, and mortality. The Jolly-Seber model will be used to determine abundance and survival rates based on the following assumptions: 1) every animal present in the population at sample period i , has the same probability of capture, p_i ; 2) every marked animal present in the population immediately after sample period i has the same probability (ϕ_i) of surviving until period $i + 1$; 3) marks are not lost nor overlooked; and 4) all samples are instantaneous, and released immediately after sampling. Statistically the effect of removal on species abundance will be determined by comparing abundances on the removal islands to abundances on the control islands by using a repeated-measures analysis of variance (ANOVA) with treatment (control or experimental), plot (island 1-6) as the between-subject factors, and time (different census days) as the within subject factor. Habitat use (aka proportional residency) will be calculated as the number of captures of an individual in a specific habitat (i.e. interior, edge, prairie) divided by the total number of captures of the individual in all habitats during the trapping session. Based on the methods used by Lin and Batzli (2001) immigration and emigration frequencies will be calculated by summing the immigration and emigration values of all individuals in a given habitat respectively. An individual whose residency value increases in a given habitat between two consecutive trapping sessions will be considered a partial immigrant. While those individuals whose residency value decreases in a given habitat will be considered partial emigrants. All of these

analyses will prove useful in determining how and if interspecific interactions between two sympatric rodent species influence population dynamics.