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Researchers at St. Lawrence University in Canton, New York compared populations of small mammals found on the 18-hole campus golf course and the nearby Kip Tract, a research and recreational woodland area. This project was part of a effort to understand the effects that habitat fragmentation can have on small mammal populations.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Managing Golf Courses for Small Mammal Diversity

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SUMMARY

Researchers at St. Lawrence University in Canton, New York compared populations of small mammals found on the 18-hole campus golf course and the nearby Kip Tract, a research and recreational woodland area. The two-year project's findings include:

- Species richness, the total number of species of small mammals present, was similar on the golf course and woodland patches.
- There were dramatic differences in abundance of certain species between the golf course and woodland sites. In particular, diurnal squirrels were more common on the golf course than the woodland sites whereas nocturnal flying squirrels and jumping mice were more common on the woodland sites.
- The Shannon Index, which takes into account both species richness and abundance, was generally higher on the woodland than on the golf course landscape, indicating higher overall small mammal diversity on the woodland than the golf course.
- Patch size has a critical relationship with species diversity. On both the golf course and woodland landscapes, larger patches sustained higher levels of small mammal species diversity, and woodland sites in general supported higher levels of diversity than equally sized golf course sites.
- Managers may be able to increase the level of small mammal diversity on their golf courses by landscaping in such a way as to maximize the size of aesthetically pleasing "habitat patches," forested areas occurring between greens and fairways.

Who are the forgotten fauna and why do they matter?

The scene is familiar: a photograph of golfers outside on a beautiful day, getting ready to tee off at the next hole. In the photograph behind them stand several deer, heads up, alert, and beautiful. This familiar image makes clear an association many have come to expect from the game of golf, a unique opportunity to spend time outside in close contact with Nature, while pursuing a challenging sport. But how real is that connection between golf and the natural world, and can that connection be made stronger to the benefit of both the golf community and Nature?

This research examines the suitability of a golf course in northern New York as home for a variety of "forgotten fauna" - species of small, generally nocturnal mammals whose presence often goes unnoticed by golfers, but who play a key role in maintaining the ecological integrity of the course. Unlike deer, these animals never make it into the photos describing the natural beauty of a course. However, as the base of the food chain for a variety of other species, their presence is critical if golf courses are to sustain a wide variety of other species over time.

Golf courses constitute anthropogenic landscapes that can negatively impact wildlife not only by subdividing habitats but also by altering local water supply, increasing frequency of edge habitat, and through the application of pesticides and herbicides (3, 11, 18, 24). Golf courses are

A deer mouse (*Peromyscus maniculatus*) peers out of a Sherman trap. Deer mice were the most common small mammal species on both the golf course and woodland landscapes.

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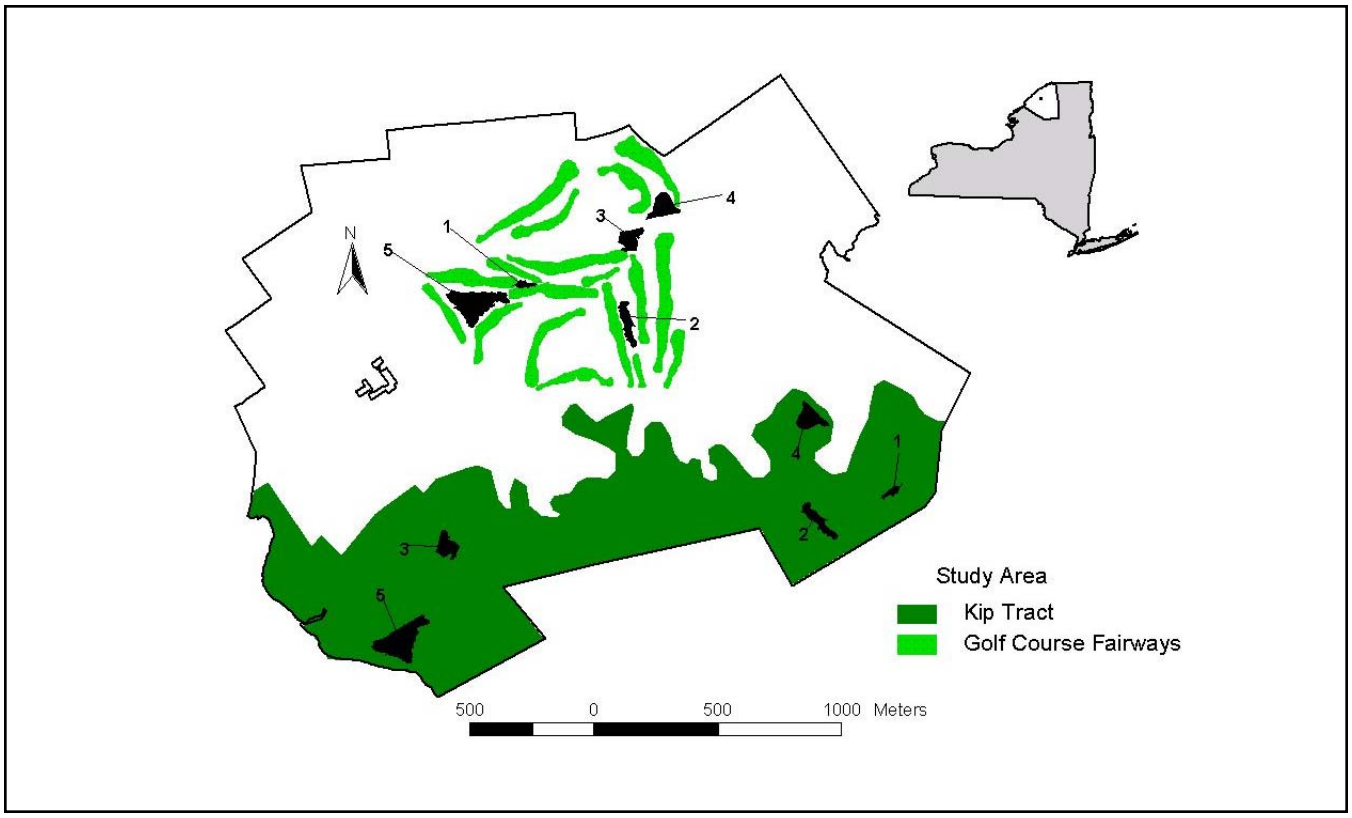

Figure 1. Study site location in northern New York State. Inset map shows location of Canton in St. Lawrence County, New York. Larger map indicates location of each of the five trapping "island" sites on the St. Lawrence University golf course and "mainland" sites on the nearby St. Lawrence University Kip Tract woodland, a research and recreation area.

also examples of fragmented landscapes in which patches of native habitat are isolated from other such patches by the playing areas on the course. In general, consequences of habitat fragmentation include abiotic changes in moisture, wind, and solar radiation as well as important changes to landscapes that can result in isolating populations from one another (20). Further, habitat fragmentation can impact populations and communities. For example, fragmentation can alter patterns of species richness and abundance (14, 16), can negatively influence demographic (21) and genetic (7, 8, 23) parameters of populations, can lead to increased likelihood of exotic species invasions (12), and can increase prevalence of vectors of human disease (1).

In spite of these problems, golf courses are also increasingly important for wildlife conservation in urbanized areas. In the United States, golf courses cover a land area larger than that of Rhode Island and Delaware combined (11). Wildlife and golf course professionals have begun to recognize the role golf courses can play in wildlife conservation through golf courses design (6, 10) and through increased interest in managing golf course landscapes as "environmentally friendly" (4, 15, 19). One aspect of that management would be to ensure that the golf course landscape is suitable for as many species as possible that may have been displaced by its construction.

How golf courses are designed as landscapes ought to be important in determining their ability to serve as suitable habitat for native flora and fauna. The ecological theory of island biogeography (17) predicts that the number of species occurring on an island should be related to the size of the island and the island's distance from the mainland. The idea of island biogeography has been widely used by conservation biologists to look at the effects of habitat fragmentation on species diversity. Habitat fragments, areas of native habitat separated from other such areas by development, are like "islands" in a "sea" of unsuitable habitat. Applying the theory of island

Site Number	Area (ha)	Trap spacing (m)	Number of traps
1	0.143	7 X 7	12
2	0.558	14 X 14	15
3	0.579	14 X 14	33
4	0.712	14 X 14	45
5	1.781	14 X 14	81

Table 1. Characteristics of trapping sites used over the course of the research project. Each site number was replicated twice, once on the golf course and once in similar habitat on the Kip Tract, a woodland adjacent to the golf course.

biogeography to fragmented landscapes, we would predict that the species diversity on habitat fragments is a function of the area of those fragments and their distance from unfragmented habitats or other sources from which species could move.

In the context of this study, it is predicted that the oftentimes aesthetically pleasing woodland patches left standing between greens and fairways on a golf course should sustain small mammal species in proportion to their size. Larger patches should sustain a higher diversity of mammal species than small patches. However, it is expected that neither large nor small patches will sustain the same level of diversity as seen in native, unfragmented woodland.

Methods

This research was conducted in St. Lawrence County, northern New York State, (44 36' N, 75 10' W) on two properties owned by St. Lawrence University, the 18-hole campus golf course and the nearby Kip Tract, a research and recreational woodland area (Figure 1). The data considered in this paper were collected over the course of two summers (2003- 2004) as part of a larger project investigating the variety of effects habitat fragmentation can have on small mammal populations (2). A series of small forest patches on the St. Lawrence University Golf Course were identified that were considered to be "islands" in a "sea" of golf course greens and fairways (Figure 1).

After identifying habitat islands on the golf course, a subset of five islands was selected on which to trap small mammals. The five islands were chosen on the basis of their functional independence from other patches (each was separated from any other forest patch by a minimum of 20 meters) and their size (Table 1). Five replicate sites on the St. Lawrence University Kip Tract were identified, the nearby woodland adjacent to campus but separated from the golf course by a river (Figure 1). For each habitat island on the golf course, an area on the Kip Tract was chosen that appeared ecologically equivalent in terms of plant species composition (2).

Live-trapping grids were established on each of the golf course islands and an identically arranged grid on each of the Kip Tract mainlands. Sherman traps (8 x 8 x 25 cm) were spaced at either 7 or 14 meters apart, along transects that conformed to the overall shape of the habitat patch. One trap was placed at each station. Animals were trapped between May and August of each year. Traps on each grid were opened for four nights per week for 8 (2004) or 9 weeks (2003) of the summer. Traps were baited in the evening with a peanut butter and oat mixture and checked the following morning.

Upon capture, the species of each animal and its trap location were recorded. Deer mice (*Peromyscus maniculatus*), woodland jumping mice (*Napeozapus insignis*) and red-backed voles (*Clethrionomys gapperi*) were also sexed, weighed, and their reproductive condition noted for the purpose of studying their populations in greater detail (data not included). They were also

Species	Abundance		Average Number (per 100 trap nights)		R	Occurrence (# of sites) 2003		2004	
	GC	W	GC	W		GC	W	GC	W
RODENTS									
Deer mice (*Peromyscus maniculatus*)	461	692	3.35	6.41	**1.9**	4	5	4	5
Red backed vole (*Clethrionomys gapperi*)	294	125	2.05	0.94	0.5	3	5	3	4
Red squirrel (*Tamiasciurus hudsonicus*)	115	59	1.17	0.42	0.4	4	5	5	2
Jumping mice (*Napeozapus insignis*)	1	170	0.01	1.14	**114.0**	1	4	0	3
Eastern chipmunks (*Tamias striatus*)	35	86	0.31	0.71	**2.3**	4	5	1	5
Flying squirrels (*Glaucomys spp.*)	18	53	0.12	0.28	**2.3**	2	2	0	4
Gray squirrels (*Sciurus carolinensis*)	21	1	0.11	*	0.0	4	1	1	0
Meadow vole (*Microtus pennsylvanicus*)	1	0	*	0	0.0	1	0	0	0
Common rat (*Rattus spp.*)	0	1	0	*		0	0	0	1
INSECTIVORES									
Short-tailed shrews (*Blarina brevicauda*)	16	9	0.11	0.06	0.6	1	1	3	3
Small shrews (*Sorex spp.*)	2	6	0.01	0.03	**3.0**	1	1	1	2
Hairy-tailed mole (*Parascalops breweri*)	0	1	0	0.01		0	0	0	1

* Captures per 100 trap nights is less than 0.01 with rounding.

Table 2. Small mammal species diversity observed at five golf course and five "control" woodland sites during 2003 and 2004. Abundance measures the absolute number of captures of each species on each landscape over the two years of the study. Average number per trap night controls for the differences in trapping effort on patches of different sizes by scaling abundance by the trapping effort on each site. R presents the ratio of average captures on the woodland sites to average captures on the golf course sites; in cases where R is greater than 1, relative abundance was higher on the woodland. When R is less than 1, relative abundance was higher on the golf course. Occurrence measures the number of golf course (GC) and woodland (W) sites (out of a possible maximum of 5) at which each species was found each year.

marked with uniquely numbered ear tags and were implanted with a unique passive integrated transponder (PIT) tag manufactured by Biomark (Boise, Idaho) by inserting the tag under the skin between the shoulders. After processing, all animals were then released at their site of capture. We locked traps open during the day. All of the trapping and animal handling techniques were approved by the St. Lawrence University Institutional Animal Care and Use Committee.

Statistical analyses were carried out using JMP statistical software (version 5.1). To compare abundance of animals between sites and landscapes, three measures of abundance were calculated: absolute abundance, average number of animals per 100 trap nights, and a relative abundance score for each landscape. Absolute abundance is the count of the total number of captures for a particular species across all sites and both years of the study for each of the two landscapes. Average number per 100 trap nights is the estimated number of times a species would be trapped in 100 trapping attempts and takes into account the fact that trapping effort was not equal between sites of different sizes.

For example, the largest site on both the golf course and woodland landscapes held 81 traps whereas the smallest site held only 12 traps. Therefore, in terms of probability, it would be much more likely to trap more animals when there are more traps present. To account for this, the total number of "trap nights" was calculated for

each site, which is equal to the total number of traps at the site multiplied by the total number of nights the traps were opened. Subsequently, the number of times each species was trapped at each site, divided by the total number of trap nights, was calculated to measure the average number of captures per trap night for each species.

Because some of these numbers were very small, each number was multiplied by 100 to determine the expected number of captures for each species over the course of 100 trap nights. Finally, in order to compare abundance between the golf course and woodland landscapes, a relative abundance index, R, was calculated by dividing the average number trapped per 100 trap nights on the woodland by the average number trapped per 100 trap nights on the golf course.

Because abundance alone is not an adequate description of species diversity, the Shannon Index, a species diversity index that takes into account not only abundance but the evenness with which species are distributed within a community, was calculated for each site for each of the two years of the study. These index values were used to compare the average level of species diversity between sites and to relate species diversity to patch size.

Results

Over the course of the study 12 different species of small mammals were caught (Table 2). The total number of species trapped (also called the species richness) was similar between landscapes, with 10 caught on the golf course and 11 caught in the woodland. If species that were trapped only as a single individual over the course of the entire study are discounted, then 8 species were caught on the golf course and 8 species were caught in the woodland (Table 2). Though species richness was similar between landscapes, the patterns in the distribution of species and their abundance were markedly different between the golf course and the woodland landscapes.

On the golf course, the most common species, in order of abundance, were deer mice, red-backed voles, red squirrels (*Tamiasciurus hudsonicus*), eastern chipmunks (*Tamias striatus*) and eastern gray squirrels (*Sciurus carolinensis*). In the woodland, the five most abundant species were deer mice, woodland jumping mice (*Napeozapus insignis*), red-backed voles, eastern chipmunks, and red squirrels. Interestingly, though four of the top five species overlapped between the golf course and woodland landscapes, jumping mice, the second most common species in the woodland, were basically absent from the golf course.

Gray squirrels, very common on the golf course, were virtually absent from the woodland. The sixth, seventh, and eighth most common species in terms of absolute abundance were the same on both the golf course and the woodland: flying squirrels (*Glaucomys spp.*), short-tailed shrews (*Blarina brevicauda*) and other shrews (*Sorex spp.*). One species, the meadow vole (*Microtus pennsylvanicus*), was caught only on the golf course (only once) whereas two species, the hairy-tailed mole (*Parascalops breweri*) and the common rat (*Rattus sp.*) were each trapped only on the woodland, also only once over the course of the study. None of the species trapped

Red-backed voles (*Clethrionomys gapperi*) such as this one are important members of the small mammal community on the St. Lawrence University golf course. Not only do they serve as prey for a variety of wildlife species (e.g. fox and owls), they are also important dispersers of fungi.

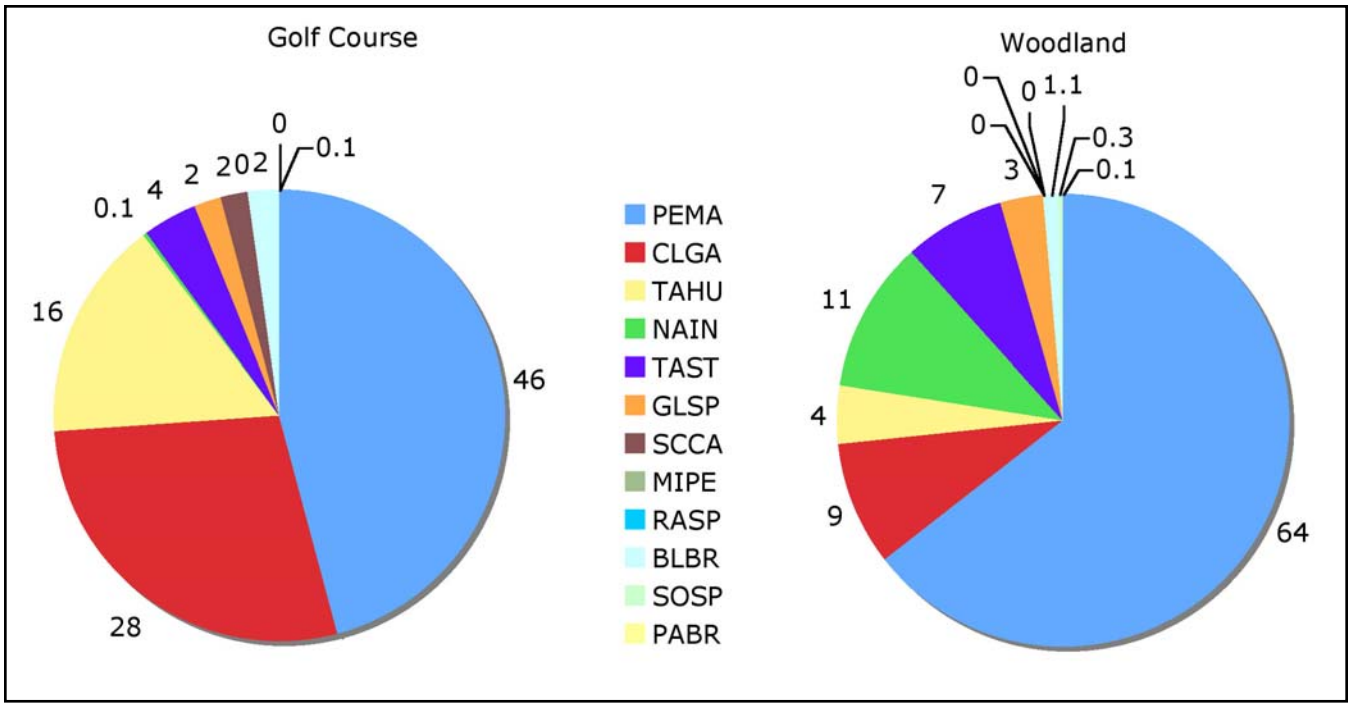

Figure 2. Percent of catch made up by each species after controlling for trapping effort for the golf course and woodland landscapes, respectively. Species are indicated by different colors on the pie charts and are referred to by the first two letters of the Genus name and of the specific epithet. For example, deer mice, *Peromyscus maniculatus*, are abbreviated as "PEMA." Numbers correspond to the expected percent of the catch based on data pooled from two summers of research.

were unusual for this area of the country.

Although species present on the golf course and the woodland landscapes were similar, there were dramatic differences in their abundance and distribution on each type of landscape (Table 2). In terms of absolute abundance, three of the five most common species on the woodland (deer mice, jumping mice and chipmunks) were more abundant on the woodland than on the golf course and two species (red-backed voles and red squirrels) were more abundant on the golf course than on the woodland.

Jumping mice, virtually absent from the golf course, were present in a ratio of absolute abundance of 170 to 1 on the woodland relative to the golf course, and gray squirrels, virtually absent from the woodland, were present on the golf course vs. the woodland in a ratio of 21 to 1. Flying squirrels, sixth most common species present on both landscape types, were more than twice as common in abundance on the woodland than on the golf course.

Several species were infrequent on both the golf course and the woodland sites and were likely to be trapped less than once in 100 trap nights (Table 2). In spite of their low abundance, there were differences between the golf course and woodland in the abundance of these species. The most striking difference in abundance was for jumping mice. The ratio in the number of jumping mice per 100 trap nights between the woodland and golf course sites was 114, indicating that for every 114 jumping mice caught on the woodland sites, only 1 was caught on the golf course sites. Chipmunks and flying squirrels were likely to be caught in a greater than 2:1 ratio on the woodland vs. the golf course, and small shrews, though uncommon on both landscapes, were three times more likely to be caught on the woodland than on the golf course landscape. On the other hand, red-backed voles, red squirrels, and short-tailed shrews were caught in almost a 2:1 ratio on the golf course compared to the woodland.

Another way to look at abundance is to examine the proportion of the catch that would be made up by each species on each landscape. On

the woodland landscape, deer mice made up more than 60% of the catch, followed by jumping mice at 11% and red-backed voles at 9 percent. Chipmunks made up seven percent of the catch, and the remaining species made up the difference (Figure 2). In contrast, on the golf course, deer mice still made up most of the catch but constituted less than 50% and red-backed voles were second at 28% of the catch. Red squirrels made up 16% of the catch on the golf course, but only 4% on the woodland (Figure 2).

Species diversity measured by the Shannon index was significantly higher on the woodland sites than on the golf course sites and varied significantly between pairs of golf course - woodland patches (Figure 3). There was also a significant landscape type X pair interaction in which there was a pronounced increase in diversity on the smallest and largest woodland versus golf course sites, respectively (Figure 3).

There was an important relationship between patch size and species diversity on both the golf course "island" sites and the woodland "mainland" sites. On both sites, species diversity, measured by the Shannon index, increased significantly with increasing patch size (Figure 4). Species diversity was also consistently higher on the woodland than the corresponding golf course sites.

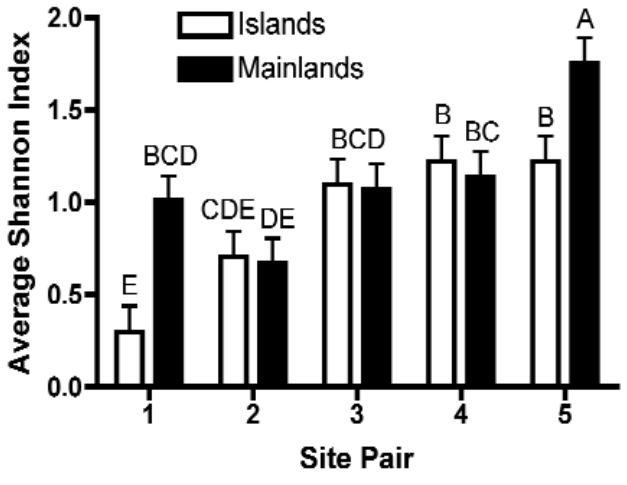

Figure 3. Differences in the mean Shannon Index between golf course "island" and woodland "mainland" trapping sites. Error bars indicate standard error of the mean. Bars that share the same letter are not significantly different.

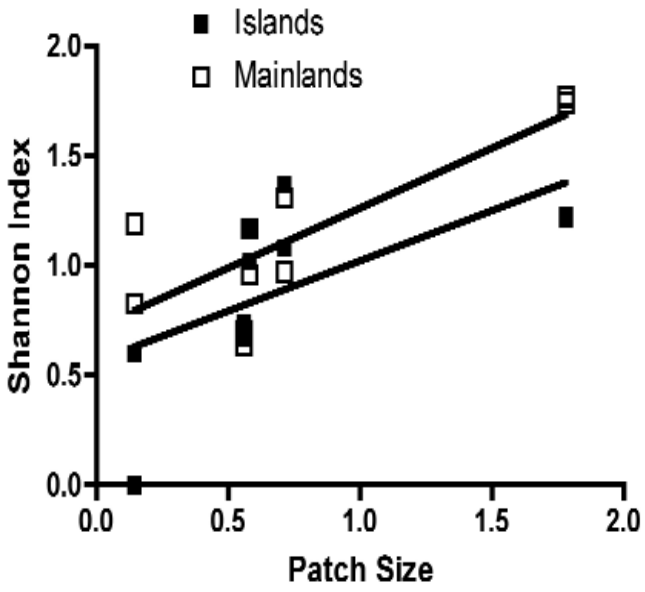

Figure 4. Larger patches have higher levels of species diversity, measured as the Shannon Index, on both the golf course "island" and the woodland "mainland" sites. Regardless of patch size, sites on the woodland tended to be more diverse than sites on the golf course.

Course design may be the key to protecting mammalian diversity

In this study, the golf course was not the equivalent of a natural woodland in supporting small mammal species. It appears that certain species are more tolerant of a golf course landscape and are thus more common on the golf course. For example, red and gray squirrels were more common on the golf course than the nearby woodland landscape. This finding is not surprising given that both species of squirrel are able to move easily around on a golf course landscape and utilize a variety of the different "habitat patches" or "islands" of habitat that exist between greens and fairways. This finding is in keeping with the expanding range of red squirrels into central hardwood forests in response to increased forest fragmentation (9).

In contrast, certain other species appear relatively intolerant of the golf course landscape. For example, jumping mice, common and abundant in the woodland sites, were virtually absent from the golf course over the period of this study. Their absence from the golf course may have to do

This deer mouse has just been processed and will shortly be released in the woods. Small mammals are excellent species to use for studying diversity because they are fairly easy to catch and handle.

with their smaller body size (relative to squirrels) and inability to easily disperse onto golf course "islands" - perhaps travel across the greens and fairways presents too high a risk of predation (by avian or mammalian predators). Higher rates of local species extinction are associated with landscapes with low mean patch sizes (5) - perhaps jumping mice are not able to establish in high enough numbers to counterbalance local extinction on golf course patches.

That there was little difference in the abundance of shrews between the golf course and woodland landscape is not surprising for two reasons. First, many shrew species (*Sorex spp.*) are too small to be captured in Sherman traps and may simply have gone unnoticed. Second, in other ecologically similar areas (Prince Edward Island in Canada) surveys of forest fragments showed no association between patch size and diversity or abundance of shrews (13).

When the evenness with which species were distributed among patches on the golf course and woodland sites was taken into account through calculation of the Shannon diversity index, the golf course was significantly less diverse than the woodland. This finding is somewhat surprising given the results from at least one study from the scientific literature. Surveys of small mammals in eastern Canada showed no association between species richness, abundance, or the Shannon diversity index and patch size or shape (22).

On the St. Lawrence University golf course, the level of fragmentation is very high and patches are very small (the largest only 1.781 hectares in size), which may explain why a reduction in diversity on the golf course was observed. Further, on the golf course, patch size explained approximately 40% of the variation in diversity observed among sites, whereas on the woodland patch size explained over 60% of the variation. This suggests that on the golf course, factors other than patch size (perhaps distance from other sites) play a role in determining the level of mammalian species diversity.

In spite of these changes in species diversity in response to fragmentation on the golf course, absolute species richness compared between the golf course and woodland landscapes was similar. There were few species present on the woodland that did not occur at all on the golf course. This fact suggests that it might be possible to manage golf course landscapes in such a way that they adequately maintain local small mammal species diversity.

The key to managing golf course landscapes to maximize small mammal species diversity probably has to do with the overall golf course landscape design. This study showed a clear positive relationship between patch size and small mammal species diversity. Courses on which the habitat patches situated between playing areas are small are not likely to support a high diversity of small mammals. On the other hand, if golf courses are designed in such a way as to maximize the size of habitat patches, a higher level of small mammal species diversity should be expected.

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