Small mammal inventory of the Apostle Islands National Lakeshore

Gus Smith, PhD, Associate Professor of Biology and Natural Resources, Northland College, Ashland, WI 54806
Frank Maragi, Northland College, Ashland, WI 54806

Introduction

"Islands are powerful metaphors. They bring images of independent, self-sustaining refuges where the turmoil of the world is a distant noise, where life is buffered by an expanse of water" (Hunter 1990). However, islands also conjure images of small, isolated habitat patches that are difficult to get to and where it is difficult to survive due to size and disturbances. In the grand continuum of islands, the Apostle Islands fall in the small end of the distribution, ranging in size from 4069 ha to 1.21 ha. However, among the Apostle Islands, there is a modest range in area and distance to the mainland that may structure plant and animal communities of the islands.

MacArthur and Wilson (1967) suggested that one could model island community diversity and predict probability of occurrence knowing extinction probabilities and colonization probabilities. The difficulty is knowing the latter parameters. Extinction probabilities are of great concern in the conservation biology movement and have been addressed more extensively than colonization probabilities. Colonization depends first upon the occurrence of the species on the mainland. Thus, island fauna are a subset of mainland fauna. In the case of mammals of the Apostle Islands National Lakeshore (APIS), the island subset depends upon the mammal communities of Ashland and Bayfield Counties. Colonization may also depend upon winter activity (Lomolino 1988, 1993) but Hanski and Peltonen (1988) and Peltonen and Hanski (1991) suggest that late summer migrations have a higher chance of establishing themselves than those occurring in winter. However in these studies, distances between islands and the mainland varied from 40 to 820 m (Hanski and Peltonen 1988), distances between the Apostle Islands and the mainland vary from a few kilometers to 24 kilometers.

Although island faunal communities depend upon the mainland source the density of these populations, per capita emigration probability, probability of surviving migration, and probability of founding a new population contingent upon arriving at a currently vacant island will greatly affect island faunal communities as well. Lomolino (1993) ignores these factors and considers 'immigration potential' to be a function of winter activity. He reasons that open water crossings are unlikely, thus winter activity is a good predictor of colonization. In the Apostle Islands, where distances between the mainland and islands are greater than those discussed in Hanski and Peltonen (1988), Peltonen and Hanski (1991), and Lomolino (1988, 1993), mammals probably cross in summer or winter. White-tailed deer and grey wolves commonly cross the ice, but may also make open water crossings, and black bears hibernate in the winter so their movements are likely limited to open water crossings.

Clearly there are at least two conflicting factors here. Grey wolves, white-tailed deer, and black bears have low densities on the mainland, in comparison to mice, voles, and shrews, and should, as predicted by Hanski (1993), have low probability of colonization. However, they are larger animals and adept swimmers and are present on several islands in the archipelago. Small body

size limits crossing great distances, especially water or ice that is free of cover and food. Therefore, density may be a predictor of colonization only for the small animals.

Objectives

In this study, we inventoried small non-volant mammals of the Apostle Islands National Lakeshore. We selected three island study areas and one mainland site. For 12 weeks, we sampled the small mammal communities of these islands to determine the presence/absence and relative abundance of small mammals.

Methods

Small mammal trapping was done in conjunction with an inventory of bats at APIS (Kruger, in progress). Trapping locations were in close proximity to bat monitoring stations and base campsites. We targeted a diversity of habitats for trapping in order to pick up as many species as possible. Trapping arrays were located during the first trapping session. Sampling effort was stratified by habitat type and by island whenever possible. Within habitat, we placed traps to maximize the probability of capturing each of the species we thought could be present on the Apostle Islands.

Study Area:

The Apostle Islands is a forested archipelago of 22 islands providing unique habitats that occur in low frequency on the mainland. With 21 of the 22 islands and a 12-mile strip of mainland coast, the Apostle Islands National Lakeshore encompasses 17204 hectares of upland mixed conifer/hardwood forest. The inventory was conducted on three islands (Devil's, Outer, and Stockton) and a section of the mainland unit (Little Sand Bay).

Little Sand Bay

The mainland unit of the Apostle Islands National Lakeshore encompasses nearly 1038 hectares and extends along the Lake Superior shore from the outlet of Saxine Creek east to Little Sand Bay (Judziewicz & Koch 1993). Two sampling areas in close proximity to the Little Sand Bay Park Service office were selected because they differed in over- and understory composition.

Site 1:

Located off Little Sand Bay Road southeast of the Park Service office, site one was established within a paper birch/mix vegetative cover. The dominant upper canopy species included paper birch, eastern hemlock, red maple, and northern white cedar. The shrub layer was sparse and included sapling balsam fir and red maple. Coarse wood debris (CWD) was relatively low in this area.

A 2,500-m^2 array was established June 3, 2003. The array was composed of six rows of six trapping stations in 10-m intervals for a total of 36 ground traps (Sherman), and six tree traps (Tomahawk 102) on each corner with two internal locations at stations 2-3 and 3-4.

Site 2:
Located near the end of Little Sand Bay Road, site two was established within a sugar maple/paper birch vegetative cover. The dominant upper canopy species included sugar maple, red maple, paper birch, yellow birch, and eastern hemlock. The shrub layer included sapling balsam fir, ironwood, and serviceberry. CWD was relatively low, although downed trees criss-crossed the plot above ground.

A 5625-m^2 array was established June 4, 2003. The array was composed of six rows of six traps at 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 4-3.

Stockton Island
Stockton Island is the largest within the Apostle Islands National Lakeshore, situated 7.9 km from the mainland and occupying an area of 4069 hectares (Judziewicz & Koch 1993). Two sampling areas were chosen for study in a red pine/eastern white pine forest community.

Site 1:
Site one was located approximately 1 km up the Tombolo trail, adjacent to a sedge bog. The upper canopy was dominated by red pine, paper birch, and black spruce. The shrub layer was composed of blueberry, leatherleaf, wintergreen, bracken fern, showy lady's slipper, and bluebead lily. CWD was relatively low.

A 5625-m^2 grid was established June 9, 2003, with the northeast boundary parallel to the sedge bog. The array was composed of six rows of six traps in 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal station at site 3-4.

Site 2:
Site two was located approximately 2 km from the visitor center along the Quarry Bay Trail. The upper canopy was relatively even-aged with several mature red pine, red maple, balsam fir, and paper birch. The shrub layer was thin, composed of sapling balsam fir and few red maples. The forest floor had little CWD, with flora taxa that included blueberry, wintergreen and bracken fern, Canada mayflower, starflower, and bunchberry.

A 2500-m^2 array was established June 10, 2003, with the northeast boundary approximately 40-m from, and parallel to, the sedge bog. The array was composed of six rows of six traps on 10-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 3-4.

Outer Island
Outer Island is one of the largest and most diverse islands. Located approximately 24 km from the mainland and occupying an area of 3237 hectares, Outer Island is the most remote of all the islands in the archipelago (Judziewicz & Koch 1993). Four sampling areas were chosen for study, each containing a unique structural or vegetative component, as compared to other areas sampled. Two areas were established on the north end and two on the south end of the island.

South end

Site 1:

Site one was located approximately 1 km up the north/south trail in a paper birch/yellow birch dominated forest community. The dominant trees of the upper canopy include sugar maple, paper birch, yellow birch, and red maple. The shrub layer was comprised of thick cover of Canada yew and slightly less mountain maple. These two species accounted for 75% of the understory. The forest floor contained a thick layer of herbaceous litter and a small amount of CWD.

A 5625-m^2 array was established June 16, 2003. The array was composed of six rows of six traps in 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 4-4.

Site 2:

Site two was located approximately 1 km northeast of the trail, along the beach, and atop the muddy banks. The composition of the forest is characteristic of a sugar maple/paper birch dominated community. The trees of the upper canopy include sugar maple, paper birch, northern white cedar, yellow birch and eastern hemlock. The understory was thick with Canada yew, mountain maple and sapling sugar maple, and occupied 78-90% of the shrub layer. The herbaceous layer was thin and CWD was relatively low.

A 5625-m^2 array was established June 16, 2003. The array was composed of six rows of six traps in 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 3-3.

North end

Site 1:

Site one was located approximately 1 km southwest of the Outer Island Lighthouse in the old growth eastern hemlock/yellow birch forest community. The dominant upper canopy is composed of eastern hemlock, yellow birch, eastern white pine and northern white cedar. The shrub layer was sparse, with some sapling hemlock, yellow birch, Canada yew, and mountain maple. The forest floor contained numerous species of moss with many large stumps and a moderate amount of CWD. The ecological significance of this area cannot be overstated. This area remains one of the Great Lakes finest examples of virgin forest.

A 5625-m^2 array was established July 14, 2003. The array was composed of six rows of six traps in 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 4-4

Site 2:

Site two was located 0.5 km southeast of site three within the old growth hemlock/yellow birch community and bordering the yellow birch/northern white cedar area. The species composition of site four was similar to site three with the exception of the border to the yellow birch/white cedar community. Near the southeastern border, there was an increase in young, even-aged eastern white cedar.

A 5625-m^2 array was established July 15, 2003. The array was composed of six rows of six traps in 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 4-4.

Devil's Island

Devil's Island is the northern-most island in the archipelago, located 14 km from the mainland. Its small size (129 ha) and rich floristic diversity combine to create a remarkable area of investigation. Two sampling areas were chosen for study, each containing a unique structural or vegetative component, as compared to other islands sampled.

Site 1:

Site one was located within a bog complex approximately 1 km from the lighthouse. The bog contained numerous stunted black spruce, yellow birch, and sapling eastern white pines. The understory component consisted of sweet gale, Labrador tea, bog rosemary, cranberry, blueberry, cotton grass, sedges, and sphagnum moss. The bog was dry (no standing water) for most sampling periods.

A 5625-m^2 array was established June 22, 2003. The array was composed of six rows of six traps in 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 4-3

Site 2:

Site two was located on the northern section of the island in one of the archipelago's best examples of boreal forest. The dominant covertype was balsam fir/paper birch. The upper canopy was dominated by mature balsam fir, paper birch, yellow birch, and eastern white pine. The ground layer was composed of numerous species of clubmoss and moss with bluebead lily, starflower, and bunchberry. The forest floor was rich in organic material and CWD.

A 5625-m^2 array was established June 22, 2003. The array was composed of six rows of six traps in 15-m intervals for a total of 36 traps (Sherman), and five tree traps (Tomahawk 102) on each corner with one internal location at station 3-4.

Trapping effort:

Traps were set in orthogonal grids along transects at 10 or 15 meter intervals. Five trapping stations per grid had Tomahawk 102 live traps attached to trees at breast height and a Sherman trap wired to the top of each. We chose to limit the number of tree traps because our cargo allowed on the boats was limited and Tomahawk traps took up too much space.

Traps placed on the ground were positioned near structural features on the forest floor such as logs, stumps, and other coarse woody debris, as well as near rocks where available, and other structural features on the forest floor. Grassy/shrubby canopy gaps, wet meadow habitats, and creek borders were targeted for meadow microtines and those species occupying wetter habitats.

Baited traps were placed in the field for 3 to 4 nights. Although, typical trapping effort consists of 7 consecutive nights (Wilson et al. 1996), due to the logistics of travel in the Apostle Islands and remote field locations, we were limited to a maximum of 4 nights per trapping week.

Traps were placed on the first day in two arrays, set, and baited. Each morning, traps were checked for captures. Captured small mammals were given a uniquely numbered Monel 101 ear tag, weighed, measured. Sex, age class, and species were determined, and animals were released. Red squirrels were released without processing because of difficulty in handling. No Sorax shrews were ear tagged and the few that survived trapping were released unmarked.

In all trapping stations except those on Stockton Island we used peanut butter with oatmeal and sunflower seeds as bait and a standard 5 x 5 cm square of cotton bedding. We did not use peanut butter in the bait on Stockton Island because of high bear density.

Deviations from tagging protocol: On the last day of trapping for each period, new captures were not tagged because the analytical methods did not require it. Because of the logistics with transportation, last days were very busy and we had to save time. These animals are indicated in the dataset with a number starting with 1000. Also, there are ~ 15 animals that are numbered 1-15 because our ear tag number sequence started with 101. These animals were marked with a unique mark with a permanent marker because we had run out of ear tags.

Results

Trap-nights:

During the twelve-week trapping schedule there were a total of 3288 trap-nights (Table 1). Trap-nights were nights where the trap was open or had a capture. Traps that were sprung during the night and did not have a capture were subtracted from the total number of trap-nights (Table 1). Total trap-nights by site were: Stockton 798, Devil's 796, Little Sand Bay 647, South Outer Island 530, and North Outer Island 517. We also maintained 14 traps around the lighthouse and pond on the north end of Outer Island for a total of 126 trap-nights but had no captures. We did not include these in the trap-night total because they were not part of the trapping arrays.

Species Diversity:

We captured a total of seven species of small mammals (Table 2). All seven were captured on the mainland site at Little Sand Bay, and each of the islands had a smaller subset of this community (Table 3). Devils Island was the most depauperate with only two species while the other three island sites each had four species (Table 3). North and south Outer Island sites had the same number of species but the south end had greater total abundance due primarily to the number of mice and voles (Table 4).

Table 1. Trap-nights in each location (where 1 trap-night equals1 trap open), Apostle Islands National Lakeshore, 2003. Closed traps are those that were disturbed by animals and thus were not open for capture.

		Plot 1		Plot 2		
Week	Island & Site	Closed	Set	Closed	Set	Total Trap-nights (Set minus Closed)
1	Sand Bay	74	138	19	92	137
2	Stockton	9	184	2	138	311
3	Outer-South	4	138	4	138	268
4	Devil's	3	138	1	138	272
5	Stockton	9	138	27	138	240
6	Sand Bay	16	184	15	184	337
7	Outer-South	4	138	10	138	262
7	Outer-North	8	138	4	138	264
7	Outer lighthouse	3	56			53[1]
7	Outer-North (pond)	1	56			55[1]
8	Devil's	6	138	7	138	263
9	Sand Bay	29	88	24	138	173
10	Outer-North	10	138	13	138	253
10	Outer lighthouse	0	18			18
11	Stockton	17	138	12	138	247
12	Devil's	7	138	8	138	261

[1]indicates traps not included in total because they were not part of a trapping array.

Table 2. Captures, recaptures, and biomass of small mammals caught during summer 2003, Apostle Islands National Lakeshore.

Species	# Captures	# Recaptures	Weight (g)
southern red-back vole	350	559	8325
woodland deermouse	174	314	3011
masked shrew	58	58	237
red squirrel	39	39	NA
eastern chipmunk	8	6	305
meadow jumping mouse	6	6	130
northern flying squirrel	4	10	329.5
Total	639	994	12497.75

Table 3. Number of each small mammal species captured by site, Apostle Islands National Lakeshore, 2003.

Species	**Common Name**	**Stockton Island**	**Little Sand Bay**	**Outer Island**	**Devil's Island**
Clethrionomys gaperi	southern red-backed vole	20	14	135	181
Tamiasciurus hudsonicus	red squirrel	14	12	13	0
Peromyscus maniculatus gracilis	woodland deermouse	10	66	98	0
Sorax cinereus	masked shrew	8	11	32	7
Tamias striatus	eastern chipmunk	0	8	0	0
Zapus hudsonius	meadow jumping mouse	0	6	0	0
Glaucomys sabrinus	northern flying squirrel	0	4	0	0

Table 4. Number of captures and recaptures at the North and South Outer Island sites, Apostle Islands National Lakeshore, 2003.

Site	Species	# Captures	# Recaptures	Weight (g)
Outer North	southern red-backed vole	25	42	561
Outer North	woodland deermouse	19	35	249
Outer North	masked shrew	23	23	89.8
Outer North	red squirrel	11	11	NA
Outer South	southern red-backed vole	110	154	2483
Outer South	woodland deermouse	79	126	1379.5
Outer South	masked shrew	9	9	33.5
Outer South	red squirrel	2	2	NA

Species Abundance and Biomass:

We caught the largest number of small mammals/trap-night on the south end of Outer Island (0.55/trap-night), followed by Devil's Island (0.40/trap-night), Little Sand Bay (0.30/trap-night), north end of Outer Island (0.21/trap-night), and Stockton (0.10/trap-night) (Table 5). Southern red-backed vole was the most abundant small mammal (Fig. 1) on all the islands but not on the mainland (Table 3). Northern flying squirrel, eastern chipmunk, and meadow jumping mouse were present on the mainland but not found on any of the islands. Among islands, red squirrel and woodland deermouse were found on Outer and Stockton but not on Devil's Island. These relative captures can be used as indicators of their dominance at each of the trapping locations (Figs. 2– 5).

Table 5. Number of recaptures by island, # of trap-nights, and capture success. Apostle Islands National Lakeshore, 2003.

Island	# Recaptures	Trap-nights	Captures/trap-night
Devil's Island	318	796	0.40
Outer Island –North	111	517	0.21
Outer Island –South	291	530	0.55
Little Sand Bay	194	647	0.30
Stockton Island	80	798	0.10
Grand total	994	3288	0.30

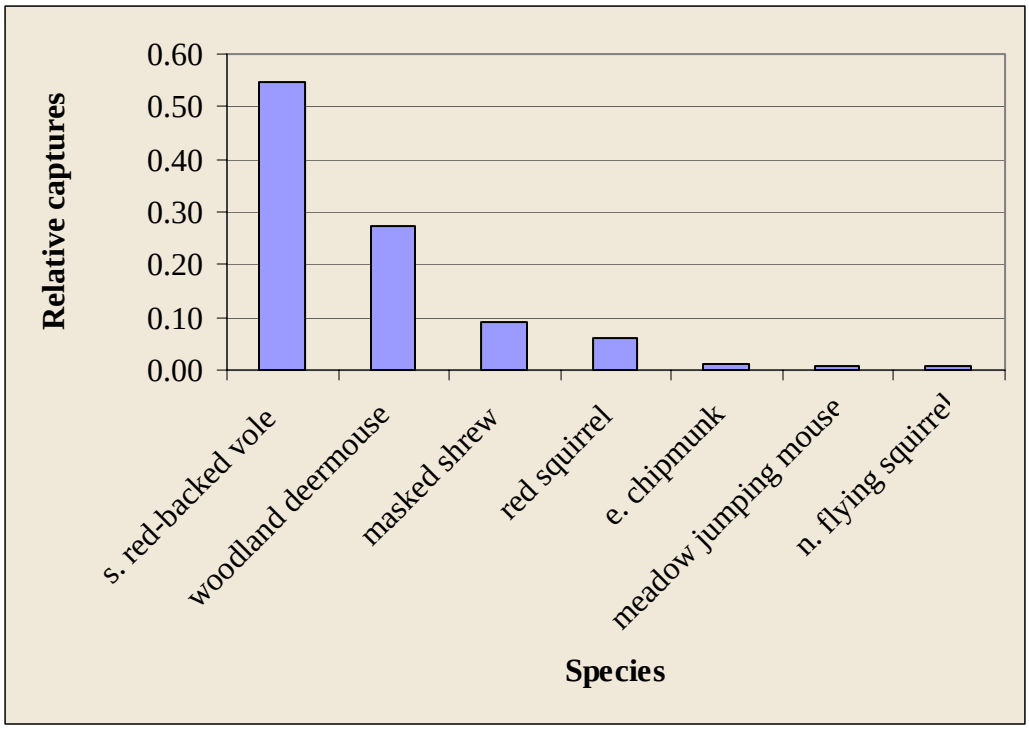

Figure 1. Relative number of captures by species captured on 3 islands and the mainland unit of the Apostle Islands National Lakeshore, WI 2003.

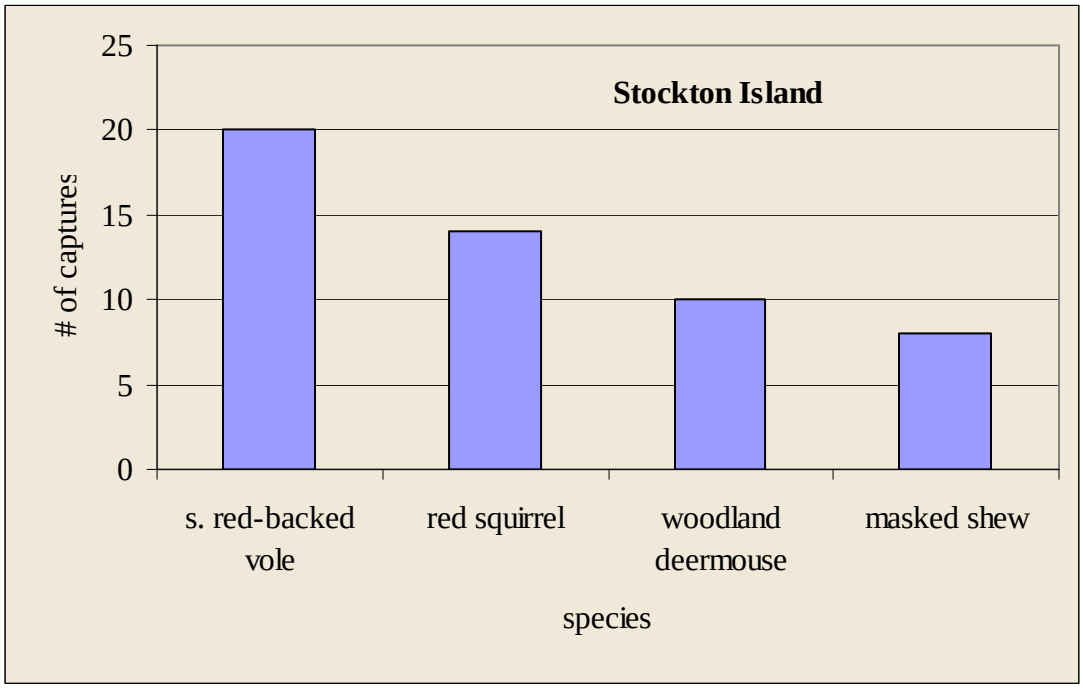

Figure 2. Number of small mammals captured on Stockton Island, Apostle Islands National Lakeshore, WI 2003.

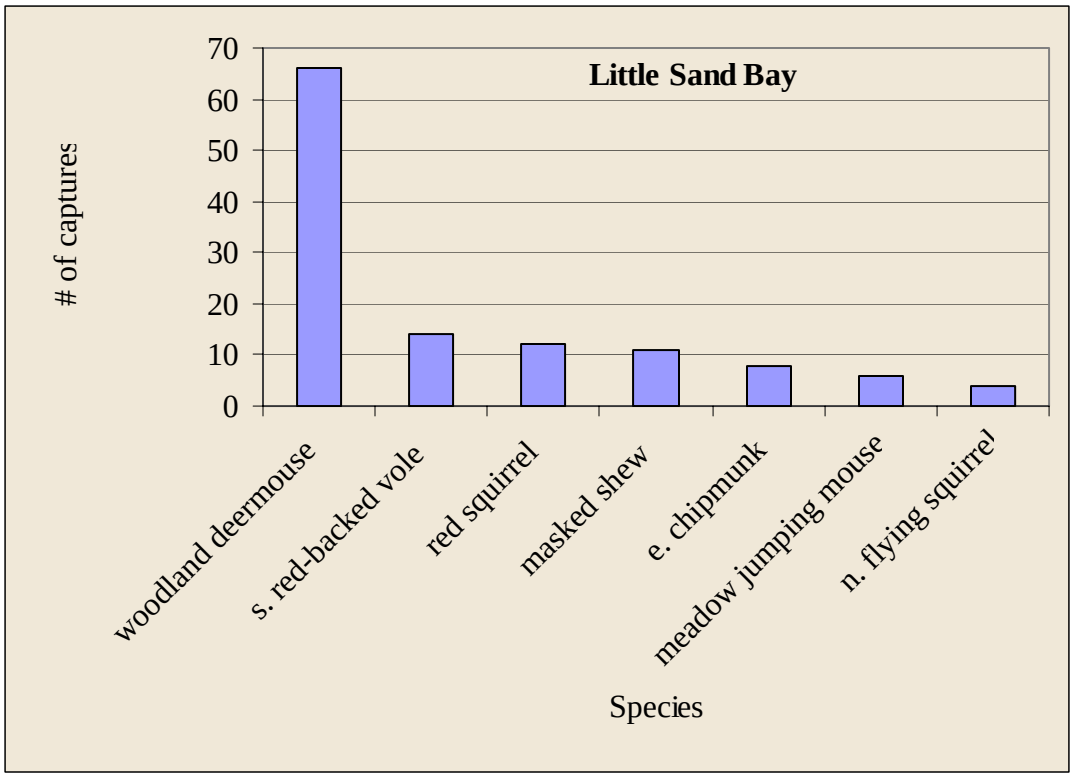

Figure 3. Number of small mammals captured at Little Sand Bay, Apostle Islands National Lakeshore, WI 2003.

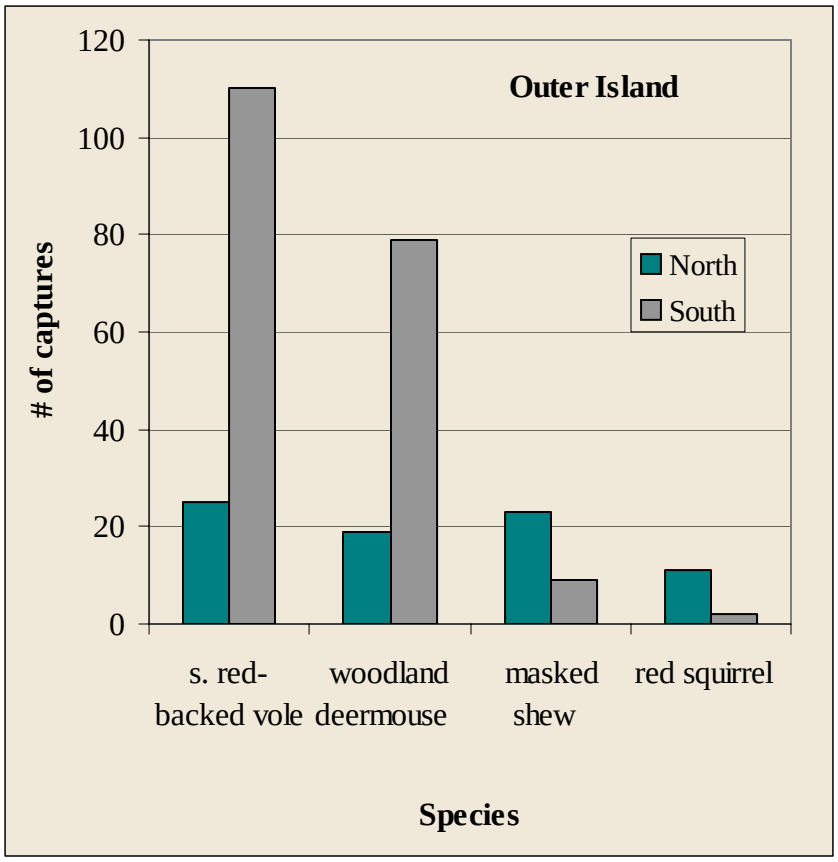

Figure 4. Number of small mammals captured from northern and southern sites on Outer Island, Apostle Islands National Lakeshore, WI 2003.

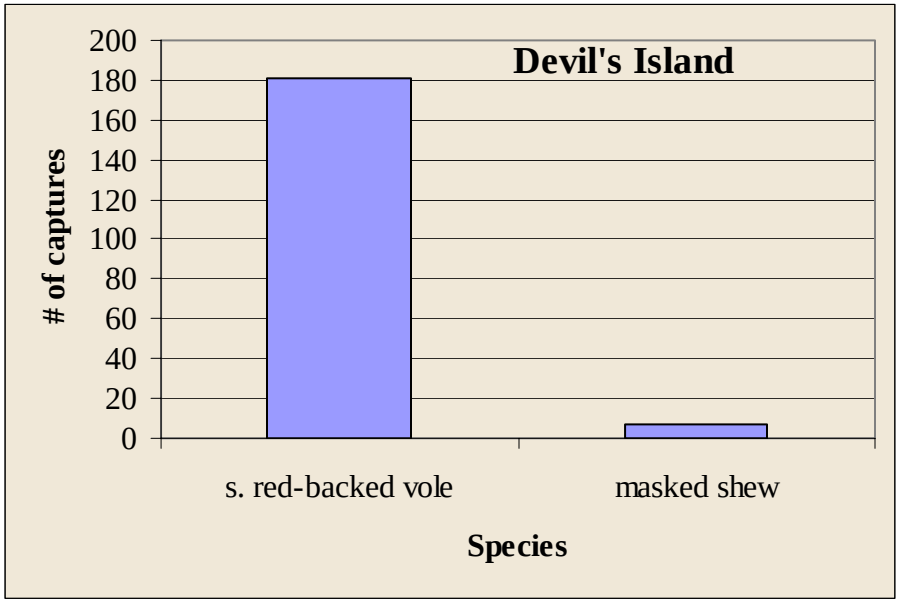

Figure 5. Number of small mammals captured on Devil's Island, Apostle Islands National Lakeshore, WI 2003.

Southern red-backed vole also had the greatest biomass, followed by woodland deermouse, northern flying squirrel, eastern chipmunk, masked shrew, and meadow jumping mouse (Fig. 6.). Red squirrels would have weighed in below southern red-backed voles but we did not weigh them (39 captures * ~200g). Though Devil's Island had the lowest species richness, it had the greatest small mammal biomass (Fig. 7.). This is an interesting finding, suggesting that the distance to Devil's and its small size may prevent colonization by the other small mammals, but that the southern red-backed vole population has expanded as expected in the absence of competition with others in its guild. It is not clear why southern red-backed voles and masked shrews have colonized Devil's Island and other species have not. Based on mainland density, woodland deermice should have colonized the island, but perhaps the boreal habitat is more suited to southern red-backed voles.

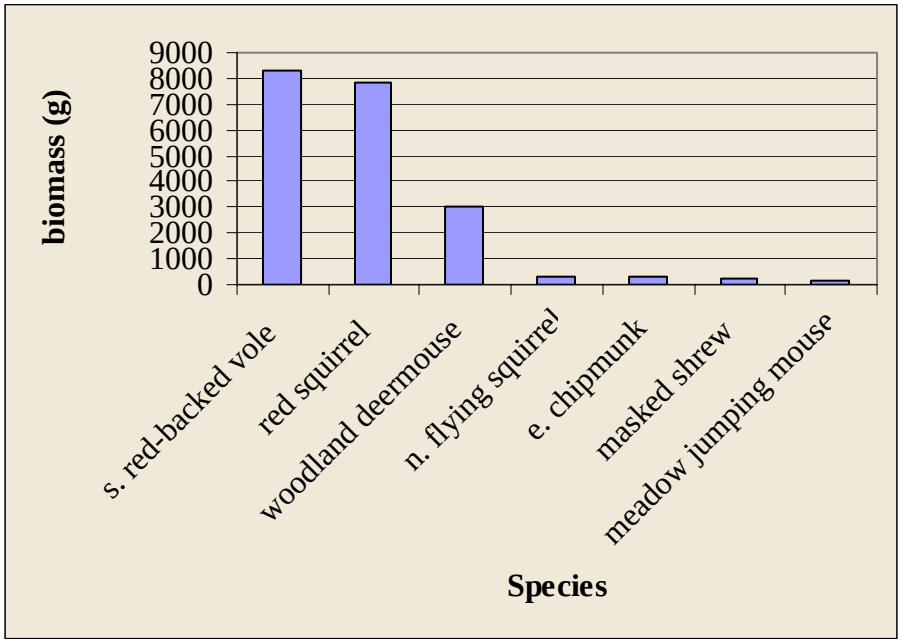

Figure 6. Total weight in biomass of each species captured on three islands and the mainland unit, Apostle Islands National Lakeshore, WI 2003.

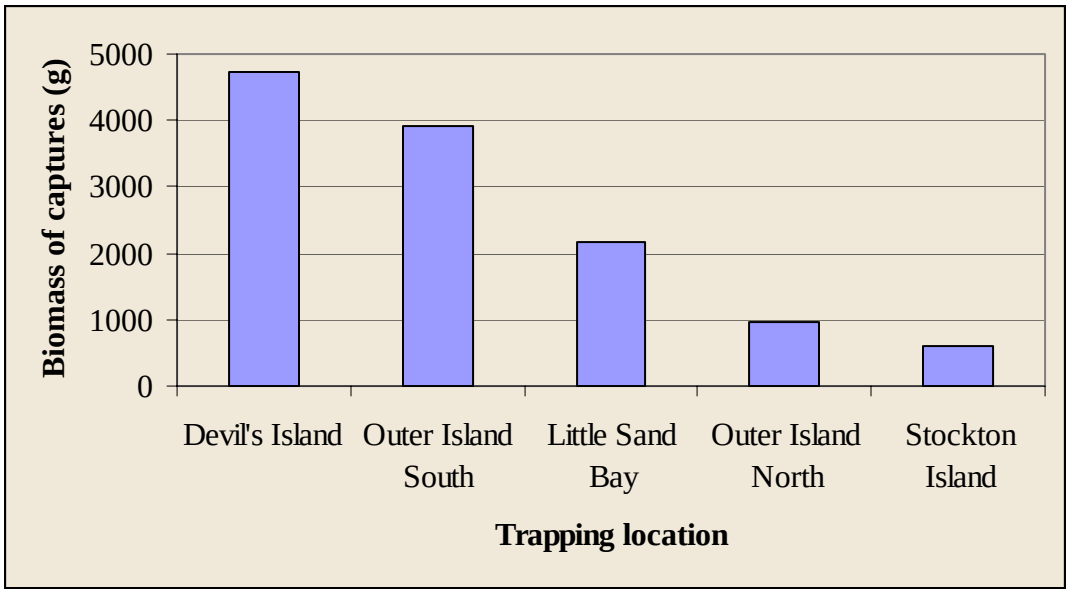

Figure 7. Total biomass of small mammals captured by trapping location, Apostle Islands National Lakeshore, WI 2003.

Discussion

There were several interesting results highlighted in this inventory. First, and perhaps most interesting, is the absence of several species. House mouse, an exotic species from Europe that have colonized just about all sites of human habitation, was not captured at any site. Given the history of European Americans in the Apostle Islands, particularly their transportation of goods to communities and lighthouse keepers, one would think that house mice could have gained access to the cargo and colonized the human inhabited islands.

Also absent, but expected based on reports from homeowners on Madeline Island, was the southern flying squirrel. In fact, southern flying squirrels were absent on the mainland despite capture success on other parts of the Bayfield peninsula (Smith, unpublished data). This species was absent from all trapping sites and perhaps has not advanced to the northern part of the Bayfield Peninsula yet.

White-footed mice also were missing from the mainland and island sites. Jackson (1961) does not report white-footed mice in either Ashland or Bayfield Counties but the lead author considered it a possibility. Because of the difficulty in differentiating white-footed mice from woodland deermice we considered the potential for misidentification of woodland deermice. However, since completion of this study, we analyzed 89 frozen specimens from 6 years of trapping throughout Ashland and Bayfield Counties and found no white-footed mice. In fact, we have since learned that about 50% of the specimens that Jackson (1961) collected and labeled white-footed mouse or woodland deermouse were incorrectly labeled (R. Bautz, *personal comm.*). Therefore, we are nearly certain that even though these two species are difficult to distinguish, we did not capture white-footed mice.

The results from Devil's Island are very interesting. Just two small mammal species were present on the island. It appears that southern red-backed voles have taken advantage of this space and filled it (e.g., competitive release). Evidence of this is demonstrated in the small mammal biomass comparisons among islands. Devil's Island has the greatest small mammal biomass, however it also has more trap-nights than either Outer Island or Little Sand Bay and has the second highest trapping success (captures/trap-night).

Stockton Island was sampled intensively (798 trap-nights), but because of the potential for black bear problems with baited traps, we did not use peanut butter for bait. Oatmeal and sunflower seeds were used instead and may have resulted in fewer captures. Stockton Island was the largest and nearest island to the mainland, so island biogeography does not explain the paucity of captures. Perhaps the absence of peanut butter as an attractant and habitats that were less productive could explain this outlier.

The results of this inventory beg for further study of the small mammal communities on the Apostle Islands. It would be interesting to know if there are more shrew species on these islands than the number of species we captured. Although we captured masked shrews, it is possible that we would have caught other species if we used pitfall traps. Pitfalls were avoided for this survey because of the impact they have on forest soils and cultural resources. However, if done carefully, impact can be minimized. Also, it would be interesting to know if there are other islands, like Devil's Island, with low richness but high abundance of those species present. Do neighboring islands have the same subset of small mammals as those we captured on Devil's Island? Have woodland deermice and red squirrels not yet colonized Devil's Island because of its size and distance from the mainland? Are those islands surrounding Devil's Island also lacking these species?

The small mammal communities on the three islands we inventoried are indeed a subset of those on the mainland. Those missing in the islands tend to be those that are inactive in winter (northern flying squirrel) and those that hibernate (eastern chipmunk and meadow jumping mouse). However, meadow jumping mice also live at low densities on the mainland, which might help explain its absence on the islands.

At larger spatial scales, Island Biogeography Theory (MacArthur and Wilson 1967) has been a helpful tool in predicting island mammalian diversity and probability of occurrence through processes of colonization and extinction, however there is current debate about which factors influence the probability of colonization. Whether island occupation depends on island size, distance from the mainland, winter activity, or mainland density, the islands we sampled appear to show some of the variability as predicted. Island by island inventories would be beneficial to track over time. Species currently absent may colonize islands in the future and alter the small mammal communities. Perhaps the small mammal community on Devil's Island is an "early" community and will increase in richness over time, while islands closer to the mainland, like Basswood and Sand, have richer small mammal communities. Tracking these communities over time will not only help the National Park Service manage the resource, but will help science understand the evolution of community dynamics.

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Appendix I. Mammal species listed in report to Apostle Islands National Lakeshore, WI 2003.

Latin Name	**Common Name**	**Reference**
Canis lupus	grey wolf	Kurta 1995
Clethrionomys gaperi	southern red-backed vole	Kurta 1995
Glaucomys sabrinus	northern flying squirrel	Kurta 1995
mus musculus	house mouse	Kurta 1995
Odocoileus virginianus	white-tailed deer	Kurta 1995
Peromyscus leucopus	white-footed mouse	Kurta 1995
Peromyscus maniculatus gracilis	woodland deermouse	Kurta 1995
Sorax cinereus	masked shrew	Kurta 1995
Tamias striatus	eastern chipmunk	Kurta 1995
Tamiasciurus hudsonicus	red squirrel	Kurta 1995
Ursus americanus	black bear	Kurta 1995
Zapus hudsonius	meadow jumping mouse	Kurta 1995

Appendix II. Plant species listed in report to Apostle Islands National Lakeshore, WI 2003.

Latin Name	Common Name	Reference
Abies balsamea L.	balsam fir	Gleason and Cronquist 1991
Acer spicatum Lam..	mountain maple	Gleason and Cronquist 1991
Acer rubrum L.	red maple	Gleason and Cronquist 1991
Acer saccharum Marshall	sugar maple	Gleason and Cronquist 1991
Amelanchier spp.	serviceberry	Gleason and Cronquist 1991
Andromeda glaucophylla Link	bog rosemary	Gleason and Cronquist 1991
Betula alleghaniensis Britton	yellow birch	Gleason and Cronquist 1991
Betula papyrifera Mashall	paper birch	Gleason and Cronquist 1991
Carex spp.	sedges	Gleason and Cronquist 1991
Ostrya virginiana (Miller) K. Koch	ironwood	Gleason and Cronquist 1991
Clintonia borealis Aiton	bluebead lily	Gleason and Cronquist 1991
Cornus canadensis L.	bunchberry	Gleason and Cronquist 1991
Cypridpedium reginae Walter	showy lady's slipper	Gleason and Cronquist 1991
Eriophorum spp.	cotton grass	Gleason and Cronquist 1991
Gaultheria procumbens L.	wintergreen	Gleason and Cronquist 1991
Ledum groenlandicum L.	Labrador tea	Gleason and Cronquist 1991
Lycopodium spp.	clubmoss	Gleason and Cronquist 1991
Maianthemum canadense Desf.	Canada mayflower	Gleason and Cronquist 1991
Myrica gale L.	sweet gale	Gleason and Cronquist 1991
Picea mariana Miller	black spruce	Gleason and Cronquist 1991
Pinus resinosa Aiton.	red pine	Gleason and Cronquist 1991
Pinus stobus L.	eastern white pine	Gleason and Cronquist 1991
Pteridium aquilinum L.	bracken fern	Gleason and Cronquist 1991
Sphagnum spp.	sphagnum moss	Gleason and Cronquist 1991
Taxus canadensis Marshall	Canada yew	Gleason and Cronquist 1991
Thuja occidentalis L.	northern white cedar	Gleason and Cronquist 1991
Trientalis borealis Raf.	starflower	Gleason and Cronquist 1991
Tsuga canadensis L.	eastern hemlock	Gleason and Cronquist 1991
Vaccinium spp.	blueberry	Gleason and Cronquist 1991
Chamaedaphne calyculata (L.) Moench	leatherleaf	Gleason and Cronquist 1991
Vaccinium spp.	cranberry	Gleason and Cronquist 1991

Appendix III. Latitude and longitude locations of the four corners of each trapping array, Apostle Islands National Lakeshore, WI 2003.

Study Area	Station 1:1	Station 1:6	Station 6:1	Station 6:6
Little Sand Bay				
Site 1	46.94598 N	46.94631 N	46.94575 N	46.94614 N
	90.88634 W	90.88599 W	90.88588 W	90.88543 W
Site 2	No signal	No signal	No signal	46.94433 W
	No signal	No signal	No signal	90.89421 N
Stockton				
Site 1	46.92770 N	46.92735 N	46.92789 N	46.92728 N
	90.55187 W	90.55206 W	90.55247 W	90.55282 W
Site 2	46.92388 N	46.92349 N	46.92417 N	46.92389 N
	90.55727 W	90.55670 W	90.55688 W	90.55627 W
Outer Island (South)				
Site 1	47.00190 N	47.00238 N	47.00249 N	47.00284 N
	90.45533 W	90.45444 W	90.45593 W	90.45516 W
Site 2	46.99734 N	46.99739 N	46.99787 N	46.99790 N
	90.45669 W	90.45569 W	90.45672 W	90.45573 W
Outer Island (North)				
Site 3	47.07384 N	47.07398 N	47.07458 N	47.07475 N
	90.42388 W	90.42484 W	90.42377 W	90.42463 W
Site 4	47.07399 N	No signal	47.07437 N	47.07339 N
	90.22320 W	No signal	90.42132 W	90.42112 W
Devil's Island				
Site 1	47.07253 N	47.07250 N	47.07328 N	47.07314 N
	90.72898 W	90.72807 W	90.72879 W	90.72805 W
Site 2	47.07700 N	47.07646 N	47.07738 N	47.07683 N
	90.73084 W	90.73039 W	90.72995 W	90.72956 W