Carnivore Diversity, Distribution, and Relation to Fine Scale Habitat Features at the University of Notre Dame Environmental Research Center

BIOS 35502: Practicum in Environmental Field Biology

Zak Lemmon

Advisor: Dave Choate

2006

Abstract:

The status of intermediate level trophic levels occupied by mid-level carnivores can sometimes be used as an indicator of the health of higher and lower trophic levels. In terrestrial forested habitats, these carnivores include animals such as fisher (*Martes pennanti*) and american marten (*Martes americana*). At the University of Notre Dame Environmental Research Center (UNDERC), there is no previous work attempting to characterize the population and distribution of forest meso-carnivores such as fisher or marten. This study investigated carnivore diversity at UNDERC in relation to three vegetation communities, maple, deciduous, and coniferous, by comparing results from baited track station surveys employing open and enclosed toner track plates and photographic stations with measured vegetation characteristics. Tree size measurements demonstrated that the coniferous areas were patchy and often contained a considerable amount of maple and other deciduous trees, while there were few differences between maple and deciduous survey areas. But structural vegetation measurements such as ground cover, canopy cover, and vertical diversity showed no significant variation at the vegetation community level (P=0.051). Total species and species specific visitation indices between sample replicate and vegetation communities were also not significantly different as determined by a series of Kruskal-Wallis tests ($p \geq 0.200$). The results of this study suggest that UNDERC has a relatively uniform physical forest structure with scattered conifer stands. This apparent uniform physical structure suggests that a carnivore will gain no benefit from vegetation characteristics by living in a specific habitat area, which is reflected in approximately even distribution of carnivores in all study areas.

Introduction:

Forest meso-carnivores play important functional roles in forest ecosystems such as regulation of prey animals, driving natural selection, and as intermediate organisms in energy flow. In addition, their presence can serve as an indicator of the health of both higher and lower trophic levels (Bull et al. 2005, Kucera and Zielinski 1995, Zielinski et al. 2005). Meso-carnivore habitat specialists, such as fisher and american marten, may also serve as an indicator of a disturbance due to their sensitivity to changes in forest structure (Buskirk and Zielinski 2003) and are consequently an important aspect of understanding forest ecosystems.

Historical treatment of meso-carnivores by humans is dominated by two main factors: trapping and habitat destruction primarily through logging. Habitat destruction in North America through large-scale logging operations has resulted in the extirpation of several forest carnivore species; for example, wolverine and red fox from the Sierra Nevada (Zielinski et al. 2005). Trapping, often in conjunction with logging, has led to a reduction in local population sizes or regional species extirpation. Fisher and marten have been especially hard hit by trapping due to their furs being highly valuable in the fur trade (Kucera and Zielinski 1995).

Even though UNDERC falls in the distributional range of several meso-carnivores, a rigorous survey for their current presence or absence has not been conducted. Since areas of UNDERC have been logged as recently as the 1970's (Mahon 2003), an evaluation of the distribution of meso-carnivores will contribute to an assessment of the current state of UNDERC's forest ecosystems. Consequently, in order to delineate the species diversity and range on UNDERC, I will survey the property specifically for meso-carnivores, stratifying the survey across three dominant vegetation types, maple (*Acer rubrum* and *Acer saccharum*), mixed-coniferous (*Picea glauca* and *Abies balsamea*), and mixed-deciduous (*Betula* spp. and *Populus* spp.).

The primary targets of this survey include fisher, american marten, long-tailed weasel (*Mustela frenata*), mink (*Mustela vison*), and raccoon (*Procyon lotor*) on the UNDERC property. Detection of other larger carnivores such as black bear (*Ursus americanus*), coyote (*Canis latrans*), or bobcat (*Felis rufus*) is also possible. However, the home range of these larger carnivores extends beyond the boundaries of UNDERC; hence detection of these carnivores in an UNDERC specific survey may reflect the presence or absence of (an) individual(s) and not of the presence or absence of a population or resident individuals. I used baited printer toner track plates and photographic stations (camera traps), to identify carnivores present based on tracks and photographs (Zielinski and Kucera 2005), and used the frequency of track detections to develop relative indices of species presence in different vegetation communities on the UNDERC property. I also evaluated the relative distribution of detected carnivores to associated habitat variables, by measuring vegetation characteristics at each survey site. By delineation of the current distribution of carnivores associated with different vegetation communities across UNDERC, this study both contributes to determining the composition of meso-carnivores and providing a baseline for further studies on the property.

Meso-carnivores are generally associated with coniferous or late-successional forests (Zielinski and Kucera 1995); hence the older spruce/fir tree stands on the UNDERC property will most likely provide suitable environments for forest carnivores;

however, some maple stands may also provide suitable environments. Forest carnivores tend to live in these older tree stands because these stands provide living space for prey, den space, and cover from possible predators. A specific example involves a study of the american marten in the Pacific Northwest, where marten prefer older forested habitats (late-successional), with ample ground and canopy cover and older and larger trees (Bull et al. 2005).

Due to the preference of most meso-carnivores for late-successional forests, I expected to detect most or all of the target species of the survey in older spruce and fir tree stands with greater canopy cover, ground cover, and forest debris. I also expected substantial detection in areas dominated by maple, which is described as a climax forest community (Barnes and Wagner 1981) and also shares some characteristics such as canopy cover and forest debris with the spruce/fir vegetation community. Finally, I expected the birch and aspen areas to be home to fewer carnivores, because birch and aspen are generally early-successional trees and unlikely to have favorable vegetation characteristics.

Materials and Methods:

Carnivore Survey:

I surveyed three dominant vegetation communities at UNDERC, maple, mixed-coniferous, and mixed-deciduous, using open and closed track plates, and photographic bait stations. Track stations consisted of two types: an enclosed, single track plate, or 2 adjacent, uncovered large plates (Zielinski and Kucera 1995). The open plates consisted of a galvanized steel base 76 cm x 81 cm x 0.16 cm, coated with printer toner medium (Belant 2003) and baited with turkey gizzards. Bait was positioned in the middle of the plate and tracks left on the plate lifted using clear packing tape. Smaller track plates (20 cm x 76 cm x 0.16 cm galvanized steel) were enclosed within plywood track boxes as described by Zielinski and Kucera (1995). Survey grids were placed throughout the property (Fig. 1) by referring to existing vegetation maps. Eight track plate stations alternating between open and closed sets were deployed along the perimeter of a 1 km^2 grid (Fig. 2), at 0.5 km intervals, resulting in four open and four enclosed plates in each grid. I also maintained a photographic bait station in the center of each grid. Cuddeback™ (Non Typical, Inc., Park Falls, WI) and Leaf River Trail Scan™ (Vibrashine, Inc. Taylorsville, MS) digital cameras were mounted approximately 0.5 m above the ground on a suitable post such as trees or fence posts. Bait for the camera traps consisted of turkey gizzards, fish, and fish remains.

Sampling took place over three one-week intervals. Three survey grids (27 stations) were surveyed simultaneously, one from each forest type, and then new grids were chosen for each of another two sampling sessions (3 samples total per each forest type). Each track station was checked for sign (tracks) every three days and reset. Camera traps were deployed in the field for two weeks and checked for pictures at the end of each sampling period. Following sampling, visitation indices were calculated with the following equation:

$$V = \frac{a}{n}$$

Where V represents the index value, a is the number of detections either for total species or specific species, and n is the number of nights run. Indices were calculated for each station individually, open and closed stations per grid separately, and at the grid level.

Survey Site Characterization:

The vegetation was characterized at three randomly selected track stations in each of the nine grids by measuring canopy cover, tree species diversity, vertical diversity, and ground cover. At each track station, I measured canopy cover using a spherical densiometer at the station and 25 m from the station at 0°, 120°, and 240°; measurements were taken and averaged for each track station. Vertical diversity of the vegetation was measured at these points by counting hits along a 4.5 m range pole at 0.5 m increments. Total vegetation volume (TVV) was calculated and used for statistical analysis through the following equation:

$$TVV = h/10p$$

Where h equals the total number of hits by vegetation summed across the $p = 4$ sampling points at each track station (Mills et al. 1991). Tree species diversity was measured by linear transects originating at the station and running 25 m at 0°, 120°, and 240°, counting trees 0.5 m from either side of the transect with a diameter at breast height (dbh) of 10 cm. A Shannon-Weiner Diversity Index (SWDI) was then generated for each surveyed station.

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

Where H represents the Shannon-Weiner Diversity Index, S is the total number of species present (species richness), and p_i indicates the portion of total species made up by the i^{th} species. Ground cover was determined in four one-m^2 plots at random distances on each 25 m transect. The cover was originally characterized by estimating percent cover per species, and later collapsed into two categories, cover or no cover.

Statistical Analysis:

Vegetation data were analyzed in four separate categories, ground cover, canopy cover, vertical density, and tree diversity. Normal distribution of the data was attained for ground cover, canopy cover, and vertical density data through an arcsine square root transformation. A nested MANOVA test comparing ground cover, canopy cover, and vertical density data between forest type and sampling grids was run. Average tree dbh and the SWDI were calculated for each surveyed station and found to have normal distribution without further manipulation. I then performed nested ANOVA tests to determine if average tree dbh and SWDI differed between the forest types. A relative biomass index for trees was created by combining all tree dbh measurements into three categories, maple, deciduous, and conifer. Nested ANOVA tests were then run to look for a difference in these indices. I ran Kruskal-Wallis and Mann-Whitney nonparametric tests to look for a difference between index of use (by carnivores) and vegetation structure, camera trap visitation was also analyzed in an identical manner. Further Mann-Whitney tests were used to look for a difference in raccoon and black bear use of the different forest types. A multiple linear regression was also performed looking for relationships between visitation rates and ground cover, canopy cover, and vertical diversity. Data collected through this survey was analyzed using Systat 11.0 (SYSTAT Software Inc., Point Richmond, VA) where statistical significance was set at $\alpha=0.05$.

Results:

Forest Type Analysis

Forest types did not differ in ground cover, canopy cover, or vertical diversity, however, a significant difference (F=5.124, df=6, *P*=0.003) was found in canopy cover between grids (Table 1, Fig. 3). On examination only the third deciduous and second maple grids differed in canopy cover (Bonferroni post hoc test, *P*=0.039). To compare the average tree dbh and SWDI, two nested ANOVA tests were performed. The ANOVA tests comparing average tree dbh and SWDI (Table 2) both did not show a significant difference (*P*≥0.05).

In addition, the total tree biomass indices were investigated for a relationship to forest type using nested ANOVA tests. One significant difference (F-ratio=7.452, df=2, *P*=0.004) was found at the habitat level and a Bonferroni post hoc test (*P*=0.014 and *P*=0.009) showed the mixed-coniferous forest type had significantly more conifer trees than both deciduous and maple forest types (Fig. 4). All forest types showed similar biomass indices for deciduous and maple trees (*P*≥0.200).

Carnivore Survey Results

During sampling, a total of 58 visits were recorded across all track plate stations, including 31 by identifiable animals and 27 that left no sign (Table 3). Identifiable visits were made by black bear, raccoon, long-tailed weasel, skunk, and coyote. Visitation indices independent of species identity calculated for each station did not display a normal distribution and transformations were not effective. Therefore, Kruskal-Wallis and Mann-Whitney nonparametric tests were performed to compare visitation rates among the grids and forest types. These tests showed no significant differences in visitation rates among forest types in a species independent model. When looking at species independent visitation rates at the grid level the only potential difference is in visitation among the mixed-maple grids (H=5.783, *P*=0.055). Mann-Whitney tests were also used to test for differences among visitation rate to open and closed track plates, but no significant differences (*P*≥0.150) in visitation were detected in any of the grids or habitat types. A Kruskal-Wallis test on the visitation rates to the camera traps and forest types also showed no significant difference (H=0.267, *P*=0.875).

Throughout sampling, black bear and raccoon accounted for the majority (83.87%) of identifiable visits to track stations. The frequency of detection of other species was too low for analysis. In light of this, Kruskal-Wallis tests comparing black bear and raccoon visitation to the different grids and forest types were performed and no significant result (*P*≥0.380) was observed.

A multiple linear regression was also performed to look for a correlation between carnivore visitation rate and three measured vegetation variables, ground cover, canopy cover, and vertical diversity. This test also showed no significant relationship (df=3, F-ratio=1.139, *P*=0.401) between visitation rate and any of the three measured characteristics.

Discussion:

Part of the original purpose of this project focused on differentiating the forest types by their vegetation characteristics and relating these differences to carnivore visitation rates. The vegetation measures I used describe two main features of an area's vegetation community, these features being structure and quality. Measured variables describing structure in the survey area are ground cover, canopy cover, vertical diversity, and average tree dbh. These factors describe physical structure of the vegetation and are most important to this study since they describe basic levels of visibility in the forest, which has an impact on a predator's ability to hunt and avoid predators (Slausen and

Zielinski 2001). A more qualitative account of the vegetation community involves the SWDI and biomass of trees, which describe tree species diversity and abundance.

After statistical analysis of the structural data, few differences were found in the data that were capable of distinguishing one vegetation community from the other two. The only distinguishing structural characteristic in the data was a difference in canopy cover between two surveyed grids, which represented the greatest difference in canopy cover values and could easily be due to an outlier. All structural components of the data suggest that distinguishing vegetation communities based on the physical characteristics of their vegetation is not possible with the data collected in this study. However, the biomass index of conifer trees implies that attempts to stratify across vegetation communities were successful at least in the case of conifer grids. My inability to find a distinct difference in the vegetation data between my deciduous and maple plots suggests a clear distinction is either not present or present on a smaller scale.

My attempt to stratify survey grids across different vegetation communities was partially successful. I was able to successfully show that the mixed-conifer grids had a larger amount of conifer trees present than the maple or deciduous grids, but was unable to distinguish maple from deciduous grids based on the vegetation data collected. However, good habitat for a predator is not decided by what type of tree is most prevalent. Predators need a surrounding that will facilitate hunting, foraging, and protection from their predators. At UNDERC, there was no difference in the structural composition of all grids. If the vegetation representation in the surveyed grids is assumed to be representative of UNDERC as a whole, then it can be assumed that forest meso-carnivores will find equally similar habitats across UNDERC and one would expect to see equal distribution of carnivores across the property as opposed to preferential selection based on habitat suitability.

This survey documented several carnivore species across the grids in a relatively uniform pattern. At the forest type level, all visitation rates ranged between 0.1 and 0.3 visits per trap night and testing did not show any significant differences in the visitation rates between forest type, grid, or open versus closed track plates. This suggests that carnivore densities are approximately the same across all grids. In conjunction with the lack of structural difference between the grids, the relative uniformity of carnivore presence indicates that the UNDERC property supports an evenly distributed carnivore population.

Two of the target species were detected, long-tailed weasel and raccoon, with the former appearing only once, while the later visited the majority of the grids. This confirms the ubiquitous nature of raccoons and their choice of habitat as described in Chamberlain et al. (2002, 2003). The lack of detection of fisher and american marten in conjunction with high raccoon detection rates raises a question as to fisher and marten relative abundance compared to raccoon. One possible explanation for the lack of fisher and marten detection is low density of these species and their typically larger home ranges compared to raccoon density and home range, where by simple probability raccoons find the track stations first. Another possible explanation for the lack of fisher and marten detection involves fisher and marten being trap shy in comparison to raccoon, meaning raccoon are more likely to investigate a track plate if they come across one than a fisher or marten. However, this may not be the case, since track plates have proven to be an effective means of monitoring fisher and marten by Zielinski et al. (2005). This suggests that lack of detection of fisher or marten on property is due to low population densities.

Raccoon and black bear accounted for approximately 80% of all identifiable visits, which implies either a large number of individuals are present on property or there are several individuals with high mobility. Based on raccoon print size (Table 4), one individual being responsible for more than two visits is unlikely; this suggests that high raccoon abundance is responsible for the high number of visits. In contrast, black bear's low density in comparison to raccoon density implies a higher mobility as a possible explanation for the large number of bear visits.

One interesting finding of this survey was the lack of significant difference in forest structure between the vegetation communities. The lack of forest structure differences was interesting since part of the central purpose of this project was to observe carnivore distribution across vegetation communities of different quality. The lack of difference between the vegetation communities made comparison of carnivore distribution in these communities not possible since all forest types had similar forest structure from the perspective of a predator. Hence, the lack of significant differences in carnivore visitation rates across the vegetation communities should be expected.

Overall, this study suggests that UNDERC has a homogenous forest structure in the surveyed areas. Therefore in future studies I would like to distribute track stations at random and not attempt to stratify the grids across vegetation community. Vegetation surveys would then be conducted at all survey stations to form a more accurate picture of forest structure than that obtained in this study. In addition, species-level track detection was limited primarily to the enclosed track plates, due to the clearing of open track plates by frequent rainfall, which rendered them unreadable. Whereas closed track plates are sheltered from rain by design. The original purpose for including open track plates was in case animals would not visit the closed track plates (Loukmas and Richmond 2002); however this does not seem to be the case, since ample visits by some species in this study to closed track plates were observed. Therefore I recommend future studies at UNDERC focus on enclosed plate designs, because visits to closed track plates are as prevalent as and more readable than visits to open track plates. In order to detect fisher and marten on track plates, I would also recommend using lure and bait specifically tailored for these species and proven by other researchers. In addition camera traps should initially be baited with a larger quantity of fish and meat, the camera traps also need to be checked every three to four days to replenish bait.

Acknowledgements:

I would like to thank Dave Choate for his mentorship, advice, and assistance throughout this project. I also want to thank Sachi Seilie, Maura Nowalk, and Lindsay Huebner for their help in checking the tracking grids, retrieving equipment, and conducting vegetation surveys. Thanks to Gary Belovsky and Karen Francl for their assistance and helpful advice on running this study. Last but not least I want to thank the Hank family for their generous contributions that make undergraduate research at UNDERC a possibility.

References:

Barnes, B. V. and W. H. Wagner. 1981. Michigan Trees: A Guide to the Trees of Michigan and the Great Lakes Region. The University of Michigan Press, Ann Arbor, Michigan.

Belant, J. L. 2003. Comparison of 3 tracking mediums for detecting forest carnivores. Wildlife Society Bulletin 31(3): 744-747.

Brown, J. S. 1988. Patch use as an indicator of habitat preference, predation risk, and competition. Behav Ecol Sociobiol 22:37-47.

Bull, E. L., T. W. Heater, and J. F. Shepherd. 2005. Habitat Selection by the American Marten in Northeastern Oregon. Northwest Science 79(1): 37-42.

Buskirk, S. W. and W. J. Zielinski. 2003. Small and mid-sized carnivores. *In* Mammal community dynamics: management and conservation in coniferous forests of western North America. Eds. C. J. Zabel and R. G. Anthony. Cambridge University Press, Cambridge, U.K.

Chamberlain, M. J., L. M. Conner, and B. D. Leopold. 2002. Seasonal Habitat Selection by Raccoons (*Procyon lotor*) in Intensively Managed Pine Forests of Central Mississippi. The American Midland Naturalist 147(1):102-108.

Chamberlain, M. J., L. M. Conner, B. D. Leopold, and K. M. Hodges. 2003. Space use and multi-scale habitat selection of adult raccoons in Central Mississippi. The Journal of Wildlife Management 67(2):334-340.

Fuller, A. K. and D. J. Harrison. 2005. Influence of Partial Timber Harvesting on American Martens in North-Central Maine. Journal of Wildlife Management 69(2): 710-722.

Haas, C. D. 2000. Distribution, Relative Abundance, and Roadway underpass responses of Carnivores throughout the Puente-Chino Hills. M.S. Thesis. California State Polytechnic University.

Hargis, C. D., J. A. Bissonette, and D. L. Turner. 1999. The Influence of Forest Fragmentation and Landscape Pattern on American Martens. Journal of Applied Ecology 36:157-172.

Krebs, J., E. Lofroth, J. Copeland, V. Banci, D. Cooley, H. Golden, A. Magoun, R. Mulders, and B. Shults. 2004. Synthesis of Survival Rates and Causes of Mortality in North American Wolverines. Journal of Wildlife Management 68(3): 493-502.

Kucera, T. E. and W. J. Zielinski. 1995. The Case of Forest Carnivores: Small Packages, Big Worries. Endangered Species Update 12(3):1-7.

Loukmas, J. J. and M. E. Richmond. 2002. Track Plate Enclosures: Box Designs Affecting Attractiveness to Riparian Mammals. The American Midland Naturalist 149(1):219-224.

Mahon, B. 2003. A Clear-cutting History Survey of the UNDERC Property. UNDERC student paper, University of Notre Dame.

Mills, G. S., J. B. Dunning, and J. M. Bates. 1991. The Relationship Between Breeding Bird Density and Vegetation Volume. Wilson Bulletin 103(3): 468-479.

Slausen, K. M. and W. J. Zielinski. 2001 Distribution and Habitat Ecology of American Martens and Pacific Fishers in Southwestern Oregon. USDA Forest Service, Pacific Southwest Research Station. Redwood Sciences Laboratory. Arcata, California. Progress Report I.

Zielinski, W. J. 2000. Weasels and Martens – Carnivores in Northern Latitudes. Ecological Studies 141:95-118.

Zielinski, W. J. and T. E. Kucera. 1995. American Marten, Fisher, Lynx, and Wolverine: Survey Methods for Their Detection. General Technical Report PSW-GTR-157, Pacific Southwest Research Station, U.S.D.A.-Forest Service, Albany, CA.

Zielinski, W. J., R. L. Truex, F. V. Schlexer, L. A. Campbell, and C. Carroll. 2005. Historical and contemporary distributions of carnivores in forests of the Sierra Nevada, California, USA. Journal of Biogeography 32:1385-1407.

Tables:

Table 1: MANOVA results using Hotelling-Lawley Trace. A MANOVA testing for differences among forest types with sampling grids nested within habitat types and the dependent vegetation measures: canopy cover, ground cover, and total vegetation volume. A significant result (*P*=0.031) was detected at the grid level between the canopy covers, a follow up Bonferroni post hoc test showed the difference to be between grids D3 and M2 (*P*=0.039). No significant result (*P*≥0.05) was detected for any of the three variables at the forest type level.

Multivariate test statistics (Hotelling-Lawley Trace)				
Source	Value	df	F-statistic	P
Forest-type	0.965	6, 30	2.413	0.051
Grid	2.463	18, 44	2.006	0.031

Univariate F-tests					
Source	SS	df	MS	F	P
Forest Type					
ASNTVV	0.262	2	0.131	3.053	0.072
Error	0.773	18	0.043		
ASNCANCOV	0.065	2	0.032	0.616	0.551
Error	0.948	18	0.053		
ASNGCLOW	0.104	2	0.052	2.335	0.125
Error	0.401	18	0.022		
Grid					
ASNTVV	0.493	6	0.082	1.914	0.133
Error	0.773	18	0.043		
ASNCANCOV	1.62	6	0.27	5.124	0.003
Error	0.948	18	0.053		
ASNGCLOW	0.028	6	0.005	0.208	0.97
Error	0.401	18	0.022		

Table 2: Average tree dbh and SWDI. Illustrates average tree dbh and the SWDI for each station individually.

	AVE DBH	SWDI
C1C1	23.25	1.04
C1C6	27.12	1.56
C1C7	16.43	0.64
C2C1	21.20	0.69
C2C3	17.80	0.00
C2C7	20.84	1.56
C3C1	31.00	0.00
C3C5	25.54	1.28
C3C8	29.68	0.00
M1C1	19.98	1.33
M1C7	29.90	0.00
M1C8	28.00	0.45
M2C2	36.57	1.10
M2C4	22.12	0.64
M2C6	24.91	0.00
M3C3	37.00	0.00
M3C7	20.09	0.41
M3C8	19.87	0.64
D1C4	12.52	0.50
D1C6	11.00	0.00
D1C7	22.03	1.10
D2C3	24.71	0.41
D2C6	22.65	0.56
D2C7	18.58	0.00
D3C1	25.55	0.00
D3C5	23.58	0.56
D3C8	25.28	1.33

Table 3: Total visitation by species. Illustration of total number of visits by species to track plates throughout the study across all nine survey grids. Animals that left no sign were characterized as unknown.

	Black Bear	Raccoon	Long-tailed Weasel	Skunk	Coyote	Unknown
# detected	9	17	1	2	2	27

Table 4: List of raccoon print sizes. Prints have dimensions ranging from 4.6cm to 6.0cm, which suggests visits were made by multiple individuals.

Raccoon Print Dimensions
4.6 x 3.5
4.7 x 3.6
4.8x3.2
4.9 x 3.3
4.9x3.8
5.0x3.5
5.0x3.6
5.0x3.7
5.0x4.0
5.1x3.9
5.2 x 3.7
5.2x4.1
5.3x4.0
5.3x5.2
5.6x4.5
5.9x4.5

Figures:

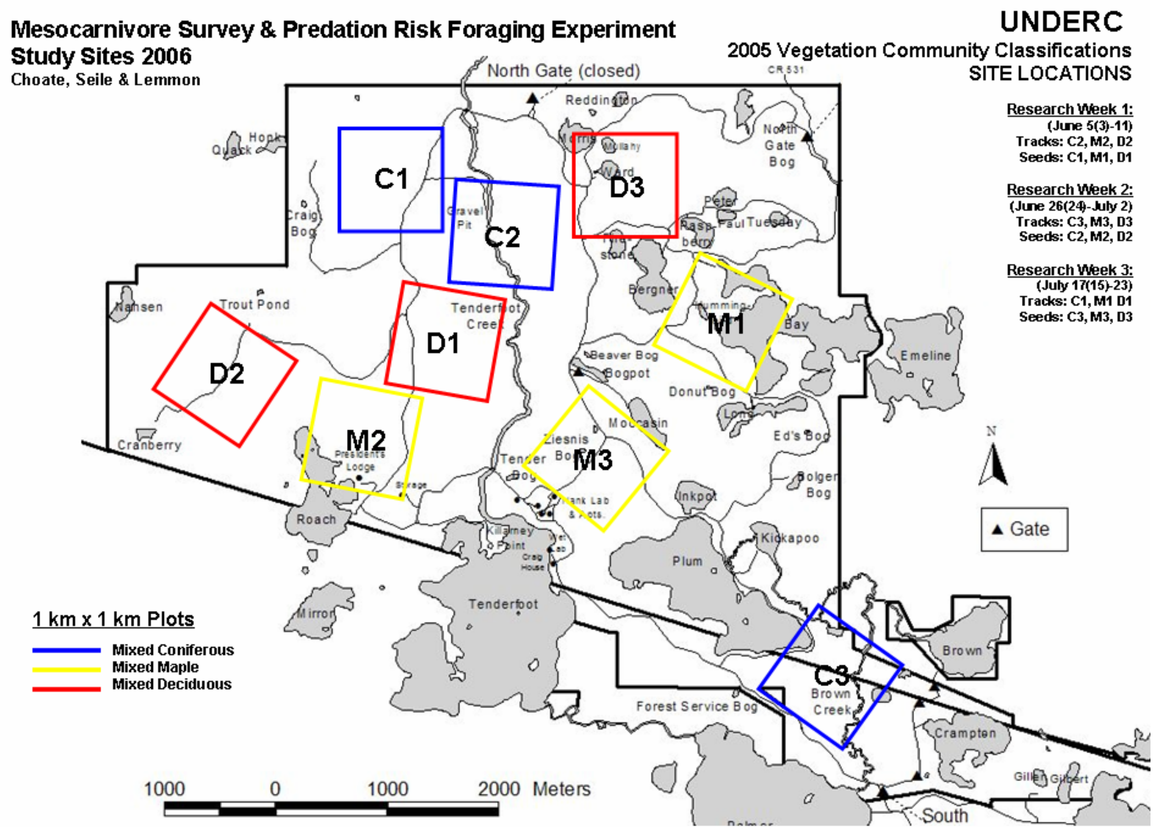

Figure 1: Property map of survey sites. Grid locations were tentatively placed by referring to existing vegetation maps of the property and individual stations were adjusted slightly to account for inaccuracies in these maps.

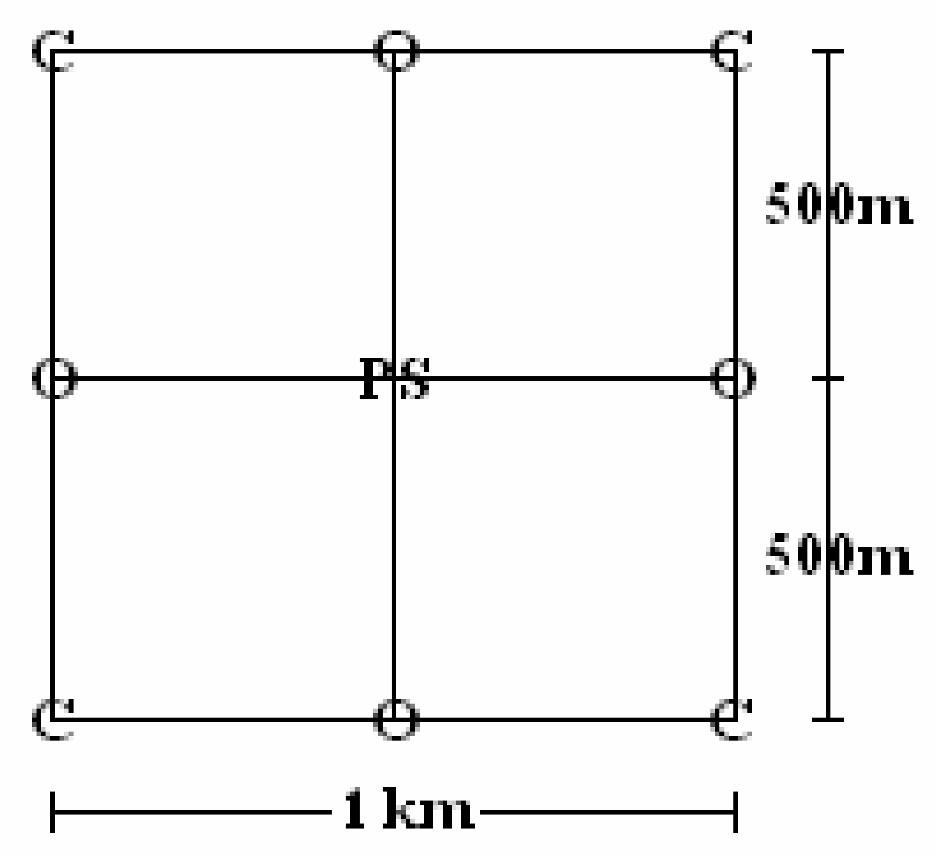

Figure 2: Diagram of the plate grid. "O" indicates an open plate station, whereas "C" indicates a closed plate station. Each station will be positioned 0.5 km from each other. A camera trap will be positioned at the central point, indicated by "PS."

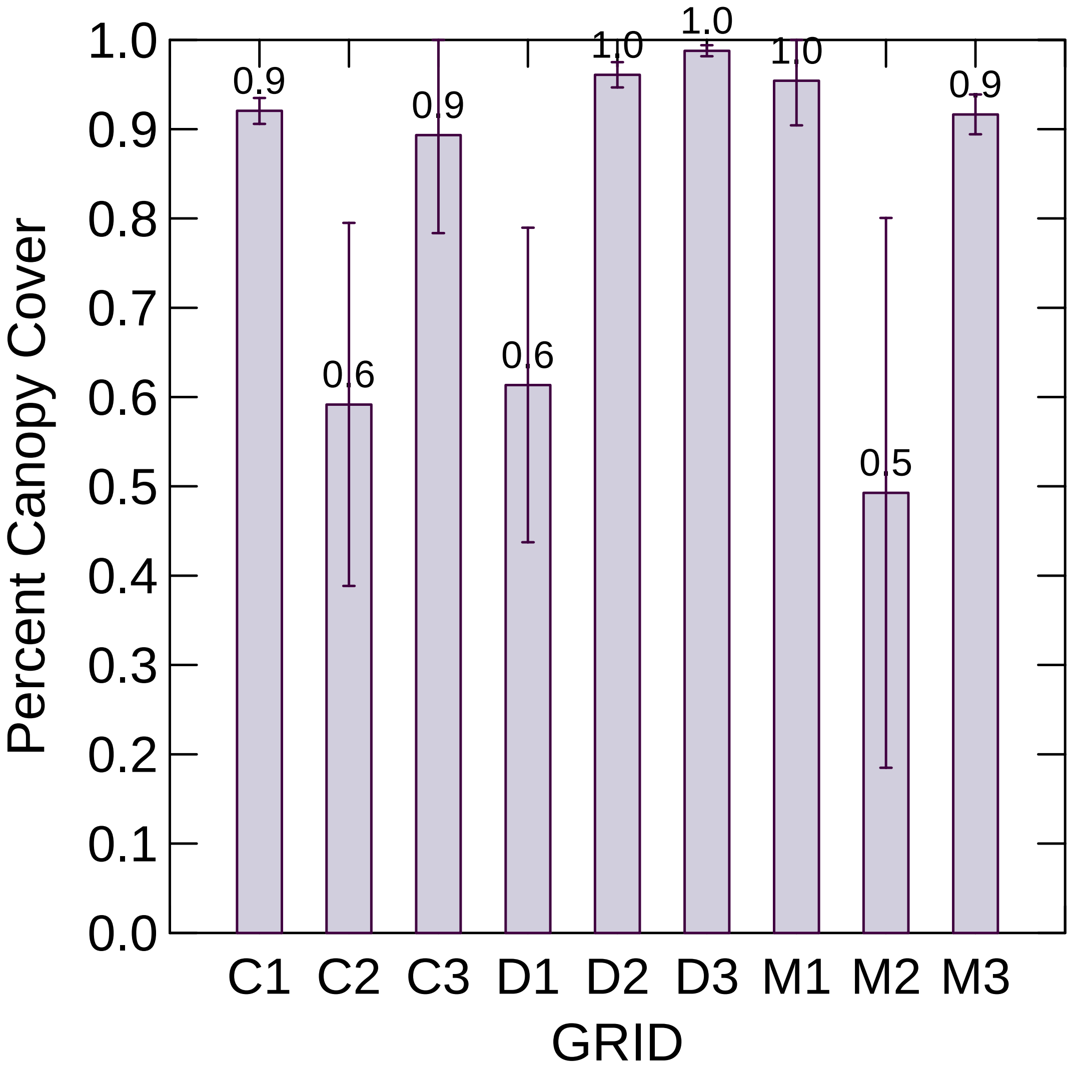

Figure 3: Percent canopy cover against each grid individually. Average canopy cover was found for each grid and compared to each other, a significant difference (MANOVA, F-statistic=2.006, *P*=0.003) was found between the two extremities, M2 and D3. This could be due to M2 being an outlier, since it approximately half the value of the other two maple grids.

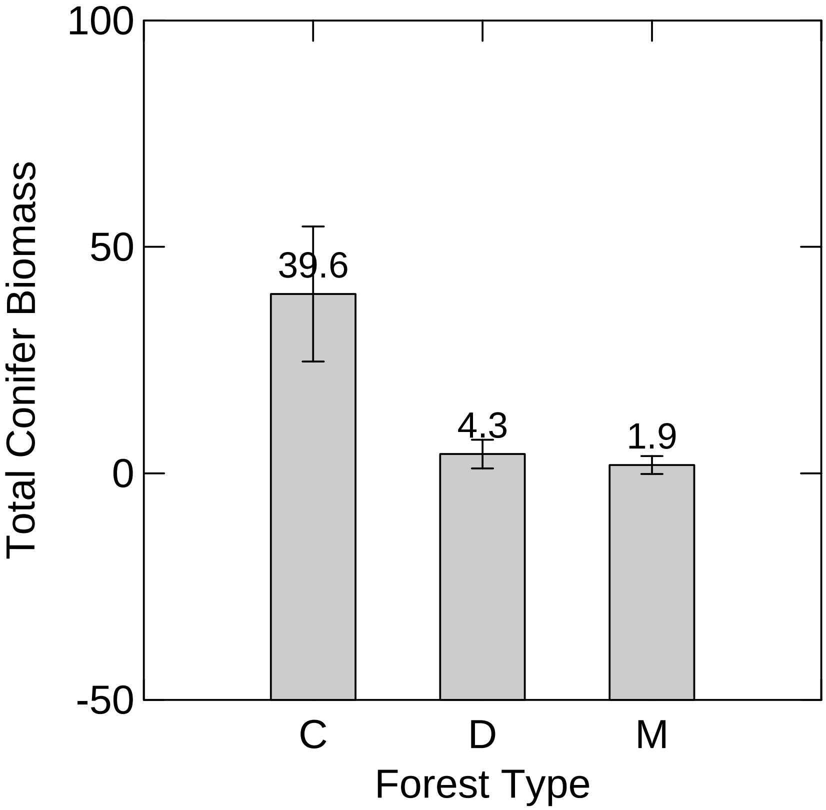

Figure 4: Index of total coniferous biomass comparison between forest types. Total coniferous biomass indices were found by summing all coniferous tree dbh's. Comparison shows the conifer grids have significantly (df=2, F-ratio=7.452, *P*=0.004) more coniferous biomass than deciduous and maple grids.