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The relationship between bird species diversity and habitat addressed through foliage height diversity and percent canopy cover in northern Michigan.

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ABSTRACT Birds were surveyed in seven plant communities in northern Michigan to assess bird diversity. Species presence was recorded by use of 10-min point counts. The habitat was assessed with a foliage height profile at twenty points within the plant community. The habitat structure was divided into three levels corresponding to the ground cover layer, the shrub layer, and the canopy. An increasing linear correlation was found to exist between bird species diversity and increase in foliage height diversity as well as between bird species diversity and greater percent canopy cover. No correlation was found between the year-round resident species and the foliage height diversity or the percent canopy cover. A positive linear correlation existed between foliage height diversity, percent canopy cover, and migratory species.

KEY WORDS: bird species diversity, foliage height diversity, habitat, percent canopy cover, vegetation, plant communities.

INTRODUCTION

Birds select habitats through a combination of factors such as terrain, substrate, landscape, vegetation composition and structure (Wiens 1969, Anderson and Shugart 1974). Environmental factors affect plant distribution and community structure, which in turn influence geographical and spatial distribution patterns in bird species (Beals 1960). The vegetation types provide different layers within the local environment, which produce greater complexity of plant community structure, and thus attract greater bird species diversity (MacArthur and MacArthur 1961, Recher 1969, Beissinger and Osborne 1982). Foliage height diversity describes the vertical vegetation complexity in the habitat.

The simplest measure of bird species diversity is species richness, or the number of species present (Buzas 1972). Other diversity measures account for both richness and abundance of each species (MacArthur and MacArthur 1961). Diversity can be influenced by plant species composition and foliage height profiles (foliage height diversity) (MacArthur and MacArthur 1961). Foliage height diversity (MacArthur and MacArthur 1961, Recher 1969, Moss 1978) and percent vegetation cover have been studied frequently (Roth 1976, Moss 1978). The former, if structural diversity is high, has a positive linear correlation with bird species diversity (MacArthur 1964, Karr 1968, Karr and Roth 1971, James and Wamer 1982), while the latter correlation can be negative (James and Wamer 1982), sigmoidal (Karr and Roth 1971), or have a positive linear relationship with the logarithm of percent canopy cover (Karr 1968, Karr and Roth 1971). Percent vegetation cover and foliage height diversity have been referred to as the vertical components of diversity influence while patchiness of habitat has been referred to as the horizontal component (MacArthur 1964, Roth 1976). Although percent vegetation cover has

been more frequently studied, percent canopy cover will be addressed in this study as a similar measurement.

In this study I have focused on the effects of plant community structure on bird species diversity in northern Michigan through a comparison of bird diversity with foliage height diversity and with percent canopy cover. The literature suggests that foliage height diversity is a major factor determining bird diversity (MacArthur and MacArthur 1961, MacArthur 1964, Karr 1968, Recher 1969, Karr and Roth 1971, Roth 1976, Moss 1978, James and Wamer 1982). Thus, I hypothesize that habitats with greater foliage height diversity will have richer and more diverse bird communities. Additionally, I hypothesize that habitats with greater percent canopy cover will have richer and more diverse bird communities.

METHODS

Study Sites. Seven representative habitat sites were selected in Kalkaska County and Crawford County in northern Michigan according to the *Natural Communities of Michigan: Classification and Description* (Kost et al. 2007). Point-counts of bird diversity took place from a point within the habitat surrounded by at least 0.4 km of habitat on each side to ensure that the birds heard were from within the habitat. The habitats included 1) hardwood-conifer swamp, 2) mesic northern forest, 3) bog, 4) dry mesic northern forest, 5) dry northern forest, 6) pine barrens savanna, and 7) poor conifer swamp (Figure 1, Table 1). All sites were at least 16.2 ha, with the exception of the open bog habitat site, which was 8.1 ha, one of the largest bogs available.

The hardwood-conifer swamp (site 1) was located on Sunset Trail Road in Kalkaska County, south of County Road 612 (UTM coordinates Zone 16T, E660553 N4957779). The canopy layer included *Abies balsamea* (balsam fir), scattered *Acer rubrum* (red maple), *Fraxinus*

nigra (black ash), *Pinus strobus* (white pine), and *Thuja occidentalis* (northern white cedar). The shrub layer included *Abies balsamea* saplings, *Alnus rugosa* (speckled alder), *Fraxinus nigra*, *Lonicera canadensis* (American fly honey suckle), and *Vaccinium myrtilloides* (hairy blueberry). The ground cover layer included *Aralia nudicaulis* (wild sarsaparilla), *Dryopteris* spp. (woodfern), *Onoclea sensibilis* (sensitive fern), and *Rubus pubescens* (dwarf raspberry). *Clematis virginiana* (virgin's bower) was a common vine in this plant community.

The mesic northern forest (site 2) was located in Kalkaska County adjacent to a dirt road near Pickerel Lake (UTM coordinates Zone 16T, E662281 N4962505). The canopy was mostly *Acer saccharum* (sugar maple), but also included *Betula alleghaniensis* (yellow birch), *Fagus grandifolia* (American beech), and *Tilia americana* (basswood). The shrub layer included *Acer saccharum* saplings, *Ostrya virginiana* (ironwood), and *Sambucus racemosa* (red elderberry). The ground cover layer included *Arisaema triphyllum* (jack-in-the-pulpit), *Caulophyllum thalictroides* (blue cohosh), *Galium triflorum* (fragrant bedstraw), *Streptopus roseus* (rose twisted stalk), *Trillium* spp. (trilliums), and *Viola canadensis* (Canada violet).

The bog (site 3) was located in Kalkaska County off of Indian Lake Road (UTM coordinates Zone 16T, E664591 N4962498). The shrub layer included *Andromeda glaucophylla* (bog rosemary), a dense growth of *Chamaedaphne calyculata* (leather leaf), and scattered *Pinus strobus* saplings (white pine). The ground cover layer included *Drosera intermedia* (spoon-leaf sundew), *D. rotundifolia* (round-leaved sundew), *Sarracinia purpurea* (pitcher plant), and *Vaccinium oxycoccos* (small-berried cranberry).

The dry-mesic northern forest (site 4) was located in Crawford County off of Manistee River Road near the intersection with Cameron Bridge Road (UTM coordinates Zone 16T, E671469 N4962891). The canopy was composed of *Acer rubrum* (red maple), *Pinus resinosa*

(red pine), *P. strobus* (white pine), *Quercus alba* (white oak), and *Q. rubra* (red oak). The shrub layer included *Acer rubrum*, *Amelanchier arborea* (shadbush), *Prunus serotina* (black cherry), *Quercus rubra*, *Vaccinium angustifolium* (low sweet blueberry), *V. myrtilloides* (hairy blueberry), and *Populus tremuloides* (quaking aspen). The ground cover layer included *Carex pensylvanica* (Pennsylvania sedge), *Gaultheria procumbens* (wintergreen), *Pteridium aquilinum* (bracken fern), and *Trientalis borealis* (starflower).

The dry northern forest (site 5) was located in Crawford County off of Manistee River Road south of its intersection with County Road 612 (UTM coordinates Zone 16T, E671517 N4958642). The open canopy included *Pinus banksiana* (jack pine) and *P. strobus* (white pine). The shrub layer included *Comptonia peregrina* (sweet fern), *Prunus pumila* saplings (sand cherry), *P. serotina* saplings (black cherry), *Quercus rubra* saplings (red oak), *Vaccinium angustifolium* (low sweet blueberry), and *V. myrtilloides* (hairy blueberry).

The pine barrens savanna habitat (site 6) was located in Crawford County off of a two track from a dirt road just west of the Manistee River (UTM coordinates Zone 16T, E670389 N4961949). The canopy was very open and included *Amelanchier* sp. (shadbush), *Prunus serotina* (black cherry), *Pinus resinosa* (red pine), and *P. strobus* (white pine). The shrub layer included *Vaccinium angustifolium* (low sweet blueberry), *V. myrtilloides* (hairy blueberry), *Comptonia peregrina* (sweetfern), and *Amelanchier* sp. *Carex pensylvanica* (Pennsylvania sedge) was the dominant herbaceous species of the ground cover layer.

The poor conifer swamp (site 7) was located in the same area as site 6 except closer to the Manistee River (UTM coordinates Zone 16T, E670548 N4961911). The canopy was composed mainly of *Picea mariana* (black spruce). The shrub layer included *Abies balsamea* saplings (balsam fir), *Acer rubrum* saplings (red maple), *Ledum groenlandicum* (Labrador tea), *Picea*

mariana saplings, and *Viburnum lentago* (nannyberry). The ground cover layer included *Coptis trifolia* (goldthread), *Rubus hispidus* (swamp dewberry), and *Sphagnum* spp. (sphagnum moss).

Bird Surveys. During the period 11 June through 24 June 2010, I visited each site seven times to conduct point-counts. Seven visits surpassed the point of diminishing returns as it exceeded the recommended five 10-minute counts per point (Buskirk et al. 1995). All counts took place between 0600 and 0900 EDT. Sites 1-3 were visited on the first counting day, June 11, and every other day after that as weather conditions permitted for the remaining two weeks (Ralph et al. 1995). Sites 4-7 were visited the second counting day, June 12, and every alternate day after that. The order in which the sites were visited each counting day was rotated to balance time-related differences in bird activity.

Each point-count lasted for ten minutes following guidelines given by Ralph et al. (1995). The 10-minute counting period began once I reached the selected point within the habitat. I recorded all birds heard or seen during those ten minutes; hence I used unlimited distance counts. Three-minute, 5-minute, and 10-minute intervals were noted to facilitate data comparisons with other studies. If an unknown call or song was heard, I attempted to visually identify the bird. If that proved impossible, the call was written down as it sounded and I attempted to identify the bird through other sources. Flyovers were indicated in the field notes, but excluded from the analyzed data.

Vegetation sampling. When determining the foliage height profile, three different layers corresponding to ground cover layer (0-0.6 m), shrub layer (0.6-6.1 m), and canopy (>6.1 m) were recorded, following Karr and Roth (1971). Within these layers, the presence or absence of vegetation was recorded and used to calculate the foliage height diversity (Karr 1968, Karr and Roth 1971). To estimate percent canopy cover, I used a piece of 0.280 x 0.432 m paper divided

into one hundred equal squares. The number of these squares that were shaded constituted the estimated percent canopy cover at that sample location. Foliage height diversity and percent canopy cover were assessed at five points located at 10-m intervals along each of the north, south, east, and west compass lines branching from the original point-count location resulting in 20 data measurements. The percent canopy cover for the habitat was the average of the 20 points. Percent canopy cover was measured at various times between 0950 and 1545 EDT excluding site 3 in which there was no canopy cover to measure. I measured percent canopy cover and foliage height profiles during the period 16 July through 22 July 2010.

Statistical analysis. The response variables included richness, abundance, bird species diversity, and guilds. I used Shannon and Weaver's diversity index to measure avian diversity and foliage height diversity (Pielou 1966). Bird species diversity was calculated based upon cumulative data from all seven counts. Birds were classified into guilds according to migrants and year-round residents. The predictor variables included foliage height diversity and percent vegetation cover. I used regression analysis (simple linear regression) to analyze each predictor variable in relation to response variables and to determine whether a statistically significant relationship was present. I also used a correlation analysis to determine the strength of that relationship.

RESULTS

Fifty-one species were identified at all seven sites over the course of the two-week birding period (Table 2). Cumulative abundance from all seven counts was very similar across the habitats ranging from 60-67 individual birds per site except for site 3 (bog) in which there were 95 individual birds identified (Figure 2). The average abundance per site was 67.57. When

site 3 was excluded, the average abundance per site was 63 individuals. Site 1 had the greatest richness of bird species with 23 species present while site 3 had the lowest richness of nine species present (Figure 3).

As foliage height diversity increased, bird species diversity increased according to a positive linear relationship with a slope of 2.0435848, a y-intercept of 0.51760314, and correlation strength r=0.83623 (Figure 4). This relationship was statistically significant at the 5% level with p=0.019. Bird species diversity also has a statistically significant positive linear relationship with percent canopy cover with a slope of 0.0162458, a y-intercept of 1.77169443, and correlation strength r=0.78976 (Figure 5). Once again the relationship was statistically significant at the 5% level with p=0.035. Bird species diversity was greatest at site 1 and lowest at site 3 (Table 3).

Forty-one of the recorded species were migrants while 10 species were year-round residents (Table 2). Migratory species and year-round residents were determined using *The Atlas of Breeding Birds of Michigan* in combination with the range maps from *National Geographic Field Guide to the Birds of North America* (Brewer et al. 1991, Dunn and Alderfer 2006). When the bird species diversities were calculated at each site as a migratory bird species diversity and as a year-round resident bird species diversity, the migratory bird species diversity showed an increasing linear relationship with both the foliage height diversity and with the percent canopy cover with equations Y=0.320593057+2.00593057X and Y=1.52171827+0.01649192X respectively (Figure 6). Both relationships were statistically significant at the 5% level with p=0.006 and p=0.028 respectively. The relationship between migratory bird species diversity and foliage height diversity had a correlation strength r=0.90145 while the relationship between migratory bird species diversity and percent canopy cover had a correlation strength r=0.80885.

The year-round resident bird species diversity analysis showed no linear correlation with the foliage height diversity or percent canopy cover (Figure 7).

DISCUSSION

The results collected support my hypotheses for bird diversity in seven plant communities in northern Michigan. Correlations were found between both foliage height diversity and bird species diversity as well as between percent canopy cover and bird species diversity. The positive linear correlation found between bird species diversity and foliage height diversity is supported by previous work in other regions (MacArthur 1964, Karr 1968, Karr and Roth 1971, and James and Wamer 1982). MacArthur (1964) found the slope of this relationship to be 1.75, Karr (1968) found it to be 1.678, and Karr and Roth (1971) found it to be 1.966 while in this study it was found to be 2.0435848. Although the slope of the relationship was slightly greater in this study, some variation is to be expected.

The relationship between bird species diversity and percent canopy cover was also found to be a positive linear correlation. Many previous researchers have looked at the relationship with percent vegetation cover rather than canopy cover, which was not found to have a linear relationship. Previous work with percent vegetation cover found the possibility of a sigmoidal relationship (Karr and Roth 1971), a negative relationship (James and Wamer 1982), or a linear relationship to the logarithm of percent canopy cover (Karr 1968, Karr and Roth 1971). None of these relationships is present in this collected data. However, percent vegetation cover and percent canopy cover are different measurements. James and Wamer (1982) found that the bird species were highly correlated with the canopy cover thus contributing support to the collected data in this study.

This positive linear correlation can partially be explained through a discussion of succession (Karr 1968, Wilson 1974, James and Wamer 1982). As succession progresses in different habitats, the average foliage height generally increases and there is an increase in complexity of foliage levels as more vegetation is added. As shown by my data, the habitats with a greater diversity of foliage height were able to support a greater diversity of bird species. Wilson (1974) suggests this greater bird species diversity is due to the addition of guilds within the habitat as succession occurs. An increase in guilds increases the niches which allows more bird species to occupy the habitat. MacArthur and MacArthur (1961) discuss the relation of niches to foliage height diversity. An increase in niches and guilds within a habitat will thus increase the diversity of bird species. While the habitats in this study were not chosen as to degree of forest succession or by predetermining guilds and niches, a similarity is possible.

The majority of the bird species occupying these plant communities were migratory species (80%). The migratory bird species diversities were linearly correlated with the percent canopy cover and foliage height diversity throughout the seven habitats, similar to previous literature (MacArthur 1964, Karr 1968, Karr and Roth 1971, James and Wamer 1982). However, no studies were done purely on migratory bird species. When analyzed apart from year-round resident bird species, the correlations with foliage height diversity and percent canopy cover were stronger than when all bird species were analyzed together. It is reasonable to conclude that this correlation is stronger because the migratory birds composed the majority of the total bird community, therefore when year-round resident species were removed the correlation became stronger.

When year-round residents were assessed apart from the total bird community no correlation was found between resident bird species diversity and foliage height diversity or

percent canopy cover. The year-round resident species constituted a much smaller portion of the total data (20% of the total bird species), so the data analysis had the potential of becoming skewed because of a small sample size. A correlation may not have been present because the sample size of resident species was too small, or because different habitats should have been chosen to adequately study relationships with resident bird species. Another possibility is that no preferential relationship exists between resident species and habitat composition even if a larger sample size was collected.

This study starts to increase the awareness of the complexity of bird habitats. While there appears to be a correlation between bird species diversity and foliage height diversity and percent canopy cover, these are only two factors within the environment that may influence bird habitat choice; therefore, this study may lead to future studies at Au Sable in coming years to continue to study the relationship between birds and their habitats. A long-term study of this type could document change within the habitats over the years. Other future studies could look more in-depth at a specific species, look for habitat-species specific correlations, look for a correlation between bird species diversity and another aspect of the habitat such as the horizontal component of habitat complexity, or begin a study into the discussion of niche or succession effects in the relationship between bird species and habitat composition.

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LITERATURE CITED

Anderson, S. H., and H. H. Shugart, Jr. 1974. Habitat selection of breeding birds in an east Tennessee deciduous forest. Ecology 55:828-837.

Beals, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. The Wilson Bulletin 72:156-181.

Beissinger, S. R., and D. R. Osborne. 1982. Effects of urbanization on avian community organization. Condor 84:75-83.

Brewer, R., G. A. McPeek, and R. J. Adams, Jr. 1991. The atlas of breeding birds of Michigan. Michigan State University Press, East Lansing, Michigan, USA.

Buskirk, W. H., and J. L. McDonald. 1995. Comparison of point count sampling regimes for monitoring forest birds. USDA Forest Service Gen. Tech. Rep. PSW-GTR-149.

Buzas, M. A. 1972. Patterns of species diversity and their explanation. Taxon 21:275-286.

Dunn, J. L., and J. Alderfer, editors. 2006. National Geographic field guide to the birds of North America. Washington, D.C., USA.

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

James, F. C., and N. O. Wamer. 1982. Relationships between temperate forest bird communities and vegetation structure. Ecology 63:159-171.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. Condor 70:348-357.

Karr, J. R., and R. R. Roth. 1971. Vegetation structure and avian diversity in several New World areas. American Naturalist 105:423-435.

Kost, M. A., D. A. Albert, J. G. Cohen, B. S. Slaughter, R. K. Schillo, C. R. Weber, and K. A. Chapman. 2007. Natural communities of Michigan: classification and description. Michigan Natural Features Inventory, Lansing, Michigan, USA.

MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. The American Naturalist 98:387-397.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.

Moss, D. 1978. Diversity of woodland song-bird populations. Journal of Animal Ecology 47:521-527.

Pielou, E. C. 1966. Shannon's formula as a measure of specific diversity: its use and misuse. American Naturalist 100:463-465.

Ralph, J. C., S. Droege, and J. R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. USDA Forest Service Gen. Tech. Rep. PSW-GTR-149.

Recher, H. F. 1969. Bird species diversity and habitat diversity in Australia and North America. American Naturalist 103:75-80.

Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57:773-782.

Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. Ornithological Monographs 8:1-93.

Wilson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

Table 1. Vegetation species found within selected habitats during foliage profile analysis.

	Habitat						
Species	Hardwood-conifer swamp	Mesic northern forest	Bog	Dry mesic northern forest	Dry northern forest	Pine barrens savanna	Poor conifer swamp
Abies balsamea	X						X
Acer rubrum	X		X	X			X
Acer saccharum		X					
Actea pachypoda	X						
Alnus rugosa	X						X
Amelanchier arborea				X	X		
Amelanchier sp.						X	
Andromeda glaucophylla			X				
Aralia nudicaulis	X						
Arctostaphylos uva-ursi					X		
Arisaema triphyllum		X					
Betula alleghaniensis	X	X					
Betula papyrifera	X						
Caltha palustrus	X						
Carex lasiocarpa			X				
Carex oligosperma			X				
Carex pensylvanica						X	

Carex sp.							X
Caulophyllum thalictroides		X					
Chamaedaphne calyculata			X				
Chelone glabra	X						
Cladina spp.					X	X	
Cladium mariscoides			X				
Cladonia sp.			X				
Clematis virginiana	X						
Comptonia peregrina				X	X	X	
Coptis trifolia	X						X
Cornus canadensis	X						X
Cornus sp.	X						
Crataegus sp.					X		
Danthonia spicata						X	
Deschampsia flexuosa					X	X	
Diervilla lonicera				X			
Diphasiastrum tristachyum					X		
Drosera intermedia			X				
Drosera rotundifolia			X				
Dryopteris spp.	X	X					X
Dulichium arundinaceum			X				
Equisetum arvense	X						
Eriophium virginicum			X				X

Fagus grandifolia	X	X					
Fraxiuns nigra	X						
Galeopsis tetrahit		X					
Galium triflorum	X	X					
Gaultheria hispidula							X
Gaultheria procumbens				X			X
Hieracium venosum					X		
Ilex verticillata							X
Juncus canadensis			X				
Juncus effuses			X				
Kalmia polifolia			X				
Larix laricina	X						X
Ledum groenlandicum							X
Liatris aspera						X	
Linnaea borealis	X						
Lonicera canadensis	X			X			
Maianthemum canadense	X			X			X
Melampyrum lineare				X	X		
Mitchella repens		X					
Mitella nuda	X						
Nemopanthus mucronata							X
Nuphar variegatum			X				
Onoclea sensibilis	X						

Oryzopsis asperifolia			X			
Osmunda cinnamomea						X
Osmunda regalis	X					
Ostrya virginiana		X				
Picea mariana						X
Pinus banksiana				X		
Pinus resinosa			X	X		
Pinus strobus	X		X	X		
Polygonum convolvulus		X				
Populus deltoides	X					
Populus tremuloides			X			
Prunella vulgaris	X					
Prunus pumila				X		
Prunus serotina	X		X	X	X	X
Prunus virginiana	X		X		X	
Pteridium aquilinum	X		X	X	X	X
Quercus alba			X			
Quercus rubra	X		X	X		
Rhamnus alnifolia						X
Rhynchospora alba			X			
Rubus hispidus						X
Rubus occidentalis		X				
Rubus pubescens	X					X

Rubus sp.		X		X			
Rumex acetosella						X	
Sambucus racemosa		X					
Sarracinia purpurea			X				
Scutellaria lateriflora	X						
Smilacina racemosa		X					
Solanum dulcamara	X						
Solidago sp.	X						
Sphagnum spp.			X				X
Streptopus roseus		X					
Thalictrum dioicum	X						
Thuja occidentalis	X						
Tilia americana		X					
Triadenum fraseri			X				
Trientalis borealis	X			X			
Trillium spp.		X					
Ulnus americana	X						
Vaccinium angustifolium				X	X	X	X
Vaccinium myrtilloides	X			X	X	X	X
Vaccinium oxycoccos			X				
Viburnum cassinoides	X						
Viburnum lentago							X
Viola canadensis		X					

Table 2. Bird species abundance in seven northern Michigan habitats.

	Habitat						
Species	Hardwood-conifer swamp	Mesic northern forest	Bog	Dry mesic northern forest	Dry northern forest	Pine barrens savanna	Poor conifer swamp
American goldfinch	0	0	2	0	0	0	0
American robin*	3	1	0	3	2	1	1
Black-and-white warbler*	3	0	0	0	0	0	1
Black-billed cuckoo*	0	0	0	2	1	0	0
Blackburnian warbler*	1	0	0	5	0	0	3
Black-capped chickadee	4	0	0	2	2	2	4
Black-throated green warbler*	1	3	0	0	0	0	0
Blue-headed vireo*	0	2	0	0	0	0	0
Blue jay	7	3	0	3	10	10	7
Canada goose*	0	0	1	0	0	0	0
Cedar waxwing	0	0	0	4	0	10	0
Chestnut-sided warbler*	0	2	0	0	0	0	0
Chipping sparrow*	0	1	0	0	3	4	1
Clay-colored sparrow*	0	0	0	0	0	0	1
Common yellowthroat*	0	0	6	0	0	0	0
Dark-eyed junco	1	0	0	0	4	0	0

Eastern wood-pewee*	0	1	0	0	1	0	0
Field sparrow*	0	0	0	0	0	4	0
Golden-winged warbler*	0	1	0	0	0	0	0
Great crested flycatcher*	0	0	0	0	2	2	1
Hermit thrush*	6	1	6	7	9	6	1
Least flycatcher*	0	0	0	1	0	0	0
Mallard	0	0	2	0	0	0	0
Magnolia warbler*	0	0	0	0	0	0	4
Mourning dove*	4	0	3	2	7	3	2
Mourning warbler*	0	3	0	0	0	0	0
Nashville warbler*	1	0	0	1	6	8	8
Northern flicker*	0	0	0	0	0	0	1
Northern parula*	0	0	0	1	0	0	0
Northern waterthrush*	0	1	0	0	0	0	0
Ovenbird*	4	19	0	10	3	0	0
Pileated woodpecker	0	2	0	0	0	0	0
Pine warbler*	2	0	0	1	3	0	1
Prairie warbler*	0	0	0	0	1	1	0
Red-bellied woodpecker	0	0	0	0	0	0	1
Red-breasted nuthatch	4	1	0	0	2	4	5
Red-eyed vireo*	0	11	0	11	0	0	0
Red-winged blackbird*	0	0	62	0	0	0	0
Rose-breasted grosbeak*	1	2	0	2	4	1	4

Ruby-throated hummingbird*	0	0	0	1	0	0	0
Scarlet tanager*	0	1	0	2	1	0	0
Song sparrow*	1	3	8	0	0	1	0
Veery*	6	0	0	0	0	0	0
White-breasted nuthatch	1	0	0	0	0	0	1
White-throated sparrow*	5	0	5	0	0	9	9
Winter wren*	4	0	0	0	0	0	0
Wood thrush*	2	1	0	0	0	0	0
Yellow-bellied sapsucker*	1	0	0	1	0	0	0
Yellow-billed cuckoo*	1	0	0	2	0	1	0
Yellow-rumped warbler*	1	0	0	0	0	0	0
Yellow warbler*	0	1	0	0	1	0	8

*Migratory species.

Table 3. Bird species diversity (BSD), foliage height diversity (FHD) and percent canopy cover (PCC) in seven northern Michigan habitats.

Habitat	BSD	FHD	PCC
Hardwood-conifer swamp	2.9048233	1.0936000	61.45
Mesic northern forest	2.4101827	1.0542958	60.00
Bog	1.3103549	0.5964626	00.00
Dry mesic northern forest	2.6104497	1.0965450	53.25
Dry northern forest	2.6159111	1.0739695	34.10
Pine barrens savanna	2.4745916	0.7740102	17.90
Poor conifer swamp	2.6583782	0.9394837	58.75

FIGURE LEGEND

Figure 1. Seven northern Michigan habitat site locations in Kalkaska and Crawford Counties in relation to the location of Au Sable Environmental Institute.

Figure 2. Total number of individual birds found at seven habitats in northern Michigan.

Figure 3. Bird species richness at seven habitats in northern Michigan.

Figure 4. Bird species diversity in relation to foliage height diversity in seven northern Michigan habitats.

Figure 5. Bird species diversity in relation to percent canopy cover in seven northern Michigan habitats.

Figure 6. A. Migratory bird species diversity in relation to foliage height diversity in seven northern Michigan habitats. B. Migratory bird species diversity in relation to percent canopy cover in seven northern Michigan habitats.

Figure 7. A. Year-round resident bird species diversity in relation to foliage height diversity in seven northern Michigan habitats. B. Year-round resident bird species diversity in relation to percent canopy cover in seven northern Michigan habitats.

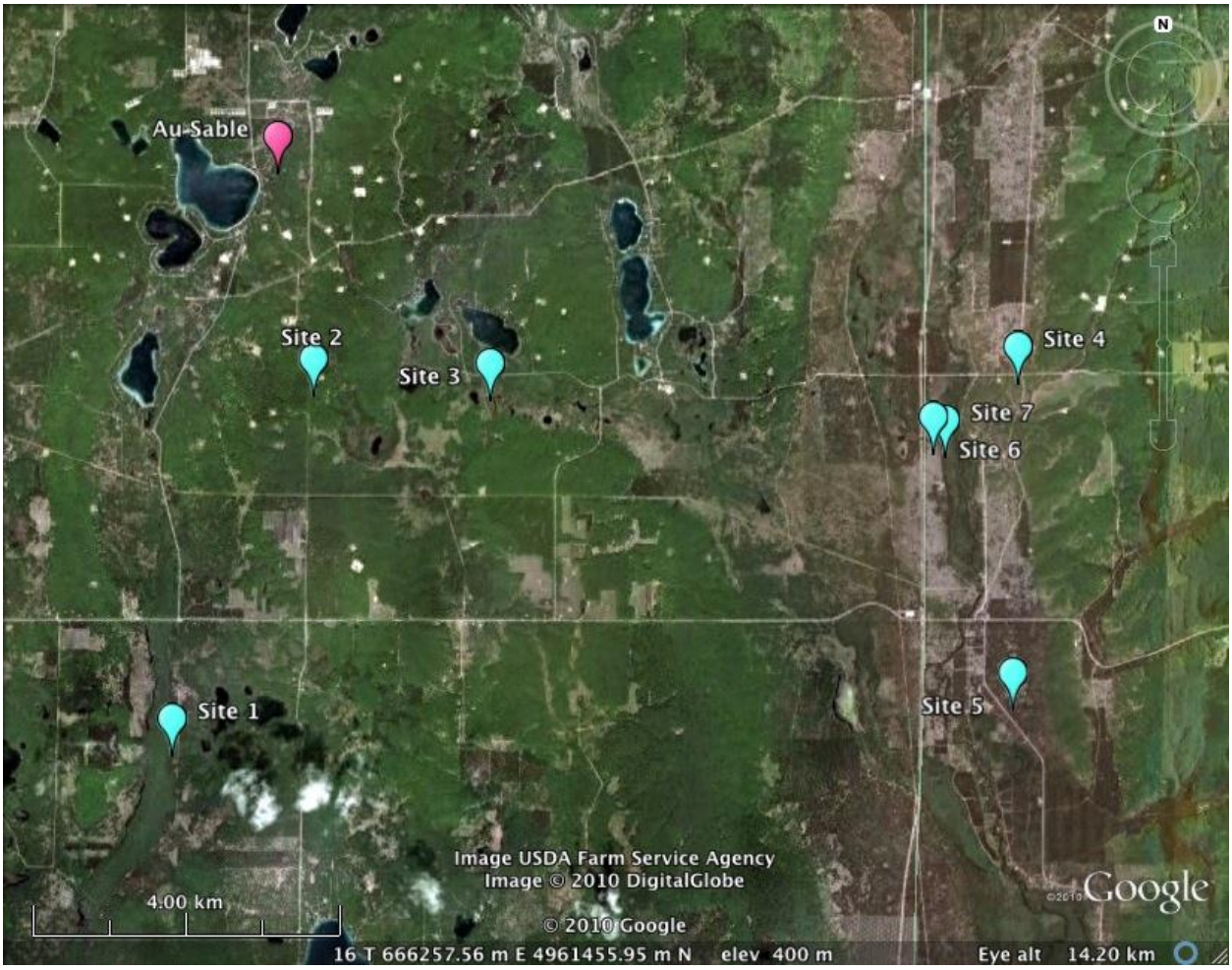


Figure 1. Seven northern Michigan habitat site locations in Kalkaska and Crawford Counties in relation to the location of Au Sable Environmental Institute.

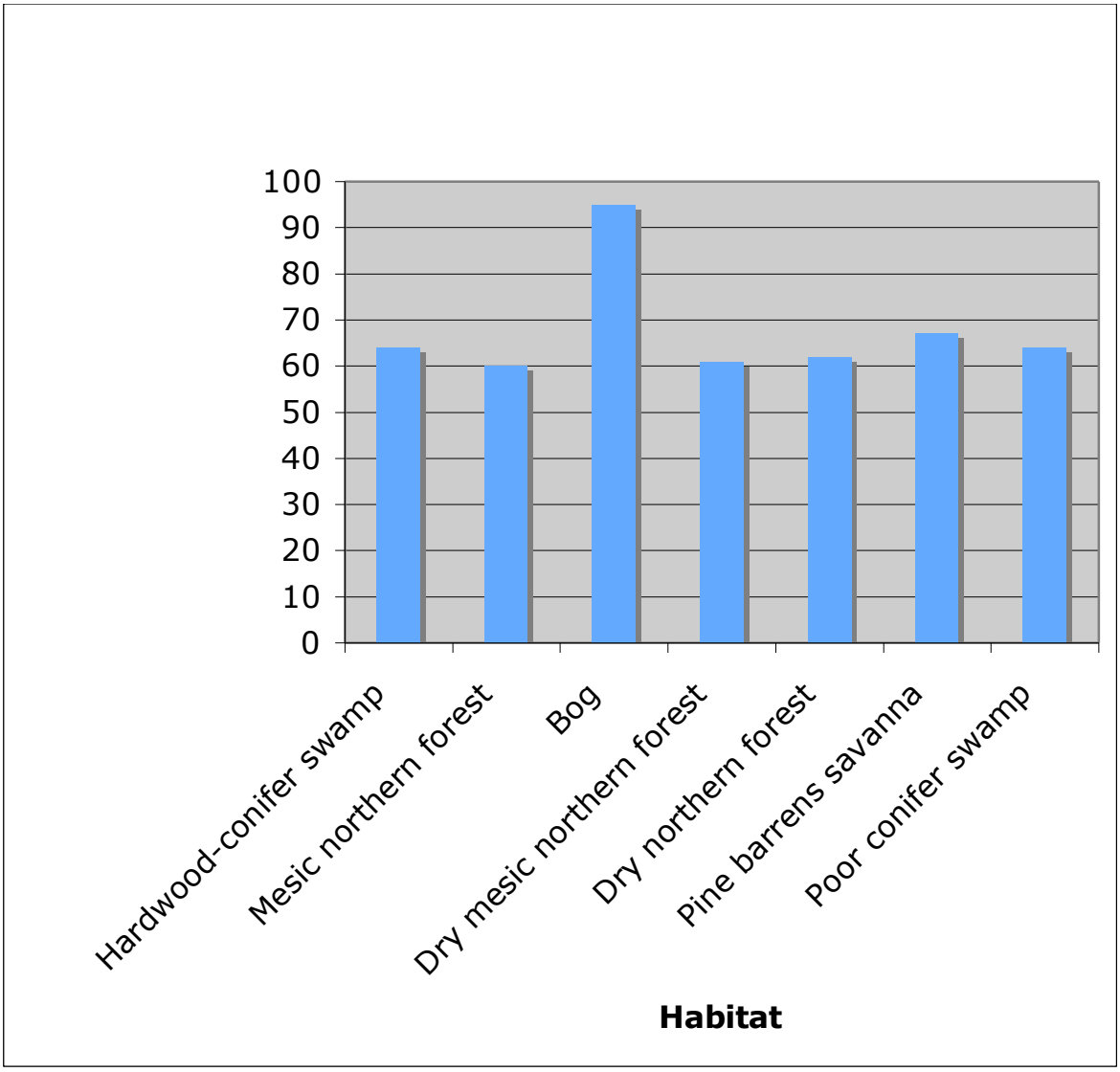


Figure 2. Total number of individual birds found at seven habitats in northern Michigan.

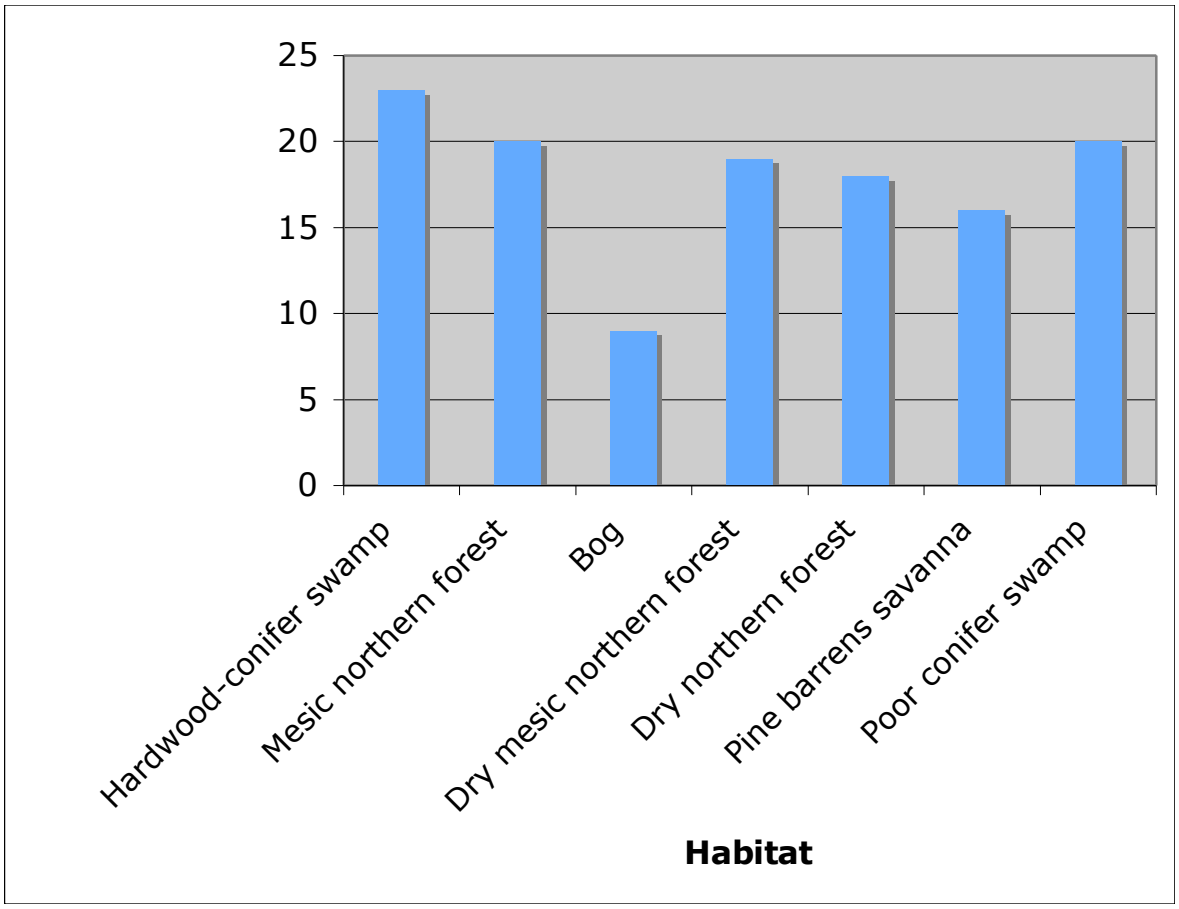


Figure 3. Bird species richness at seven habitats in northern Michigan.

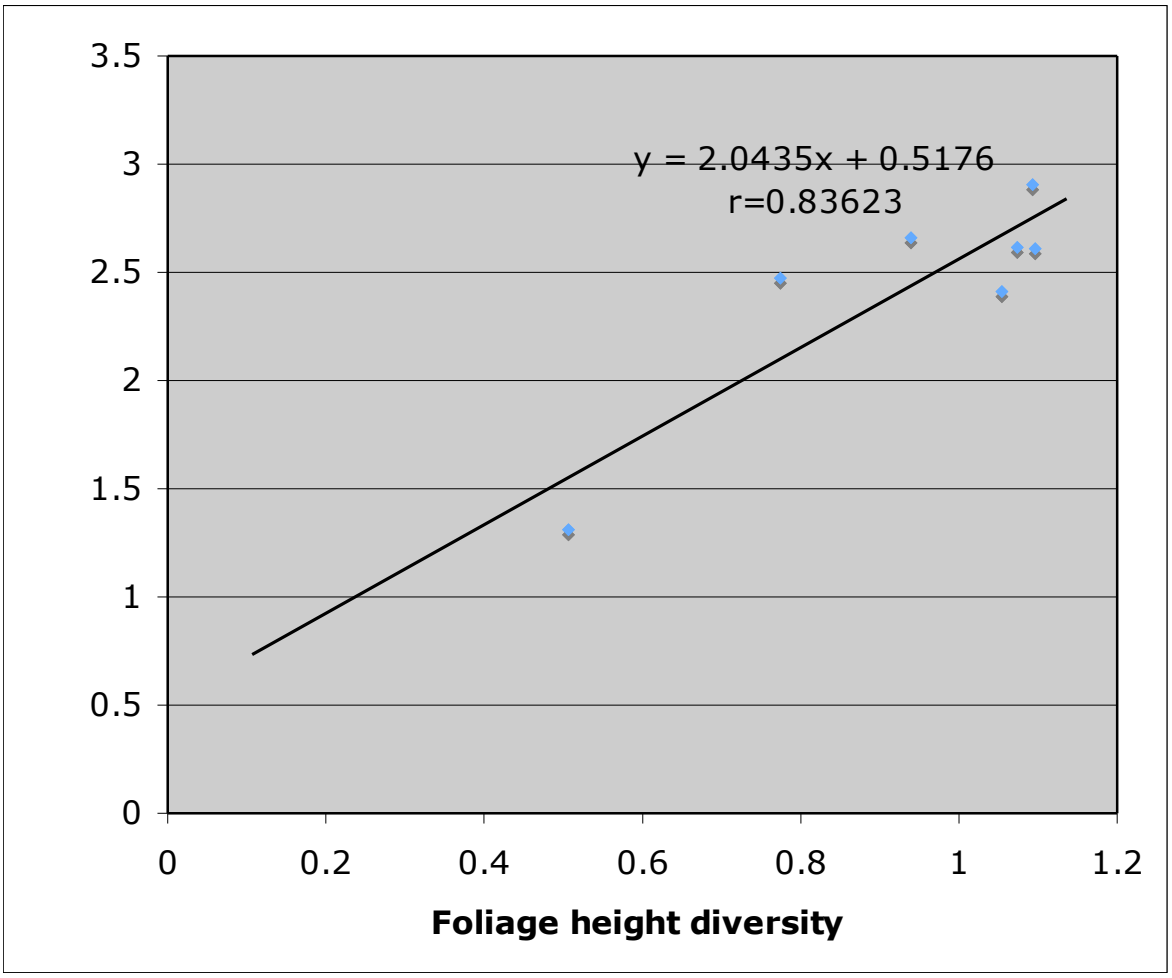


Figure 4. Bird species diversity in relation to foliage height diversity in seven northern Michigan habitats.

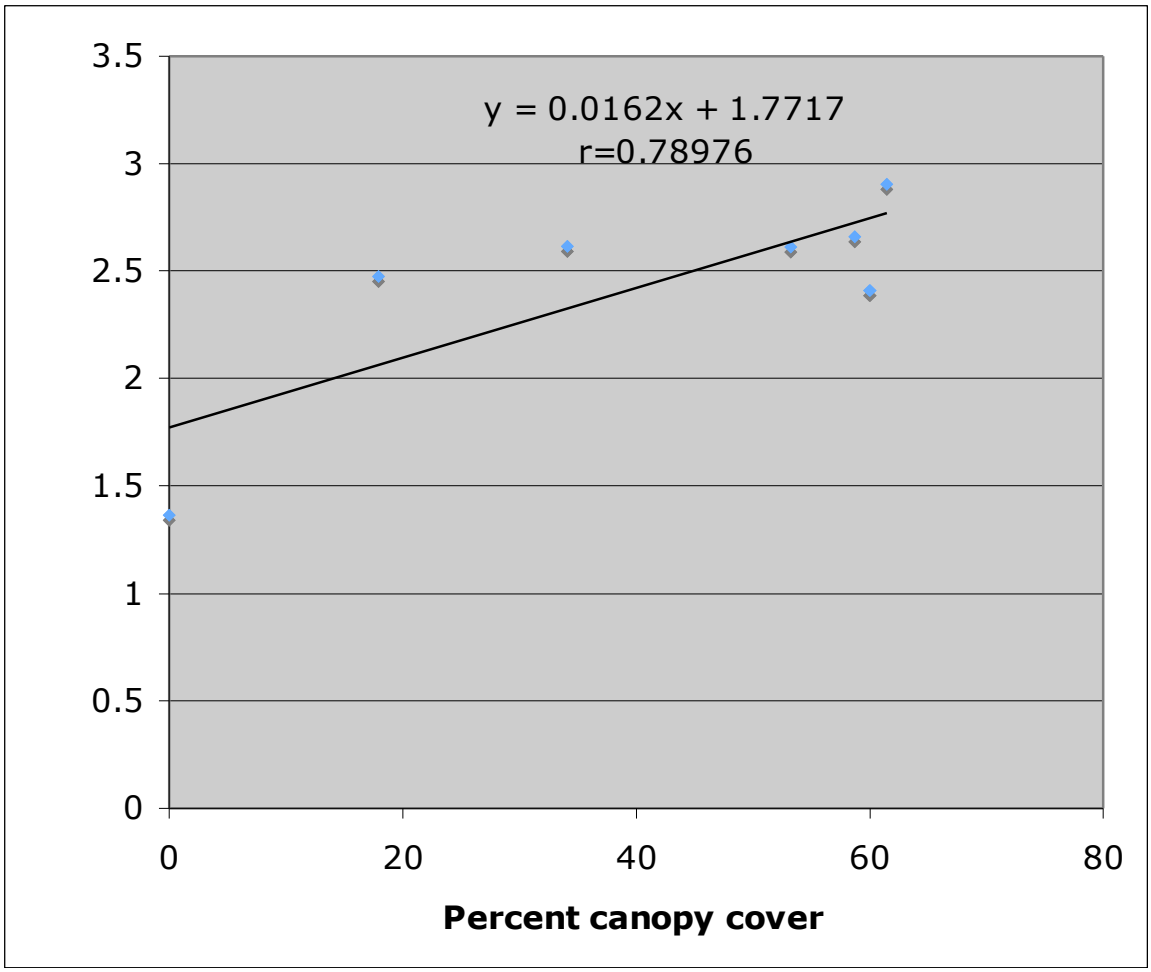
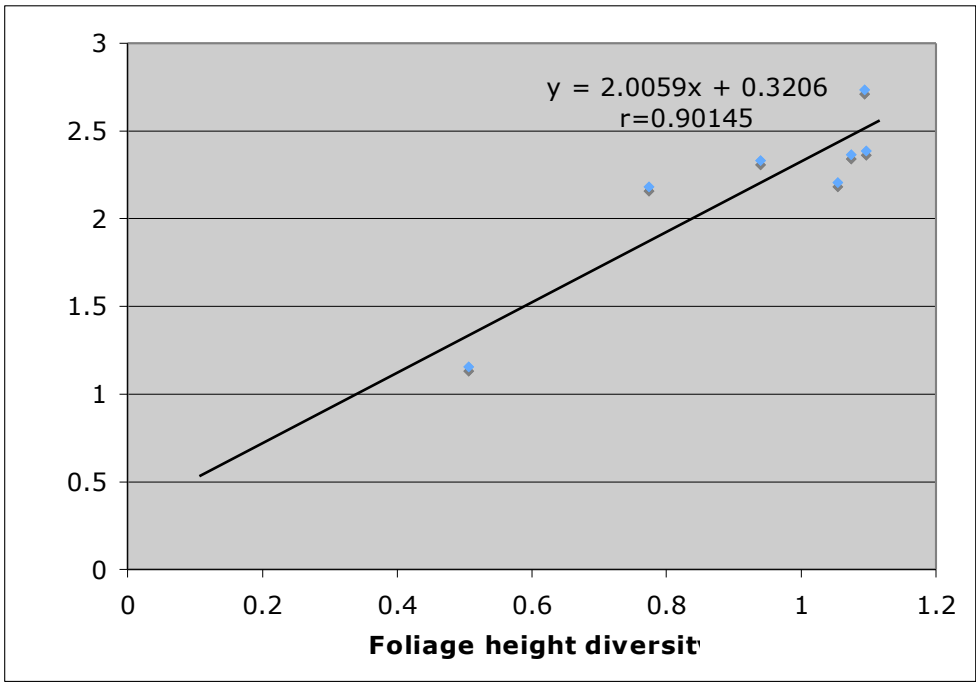


Figure 5. Bird species diversity in relation to percent canopy cover in seven northern Michigan habitats.

A.



B.

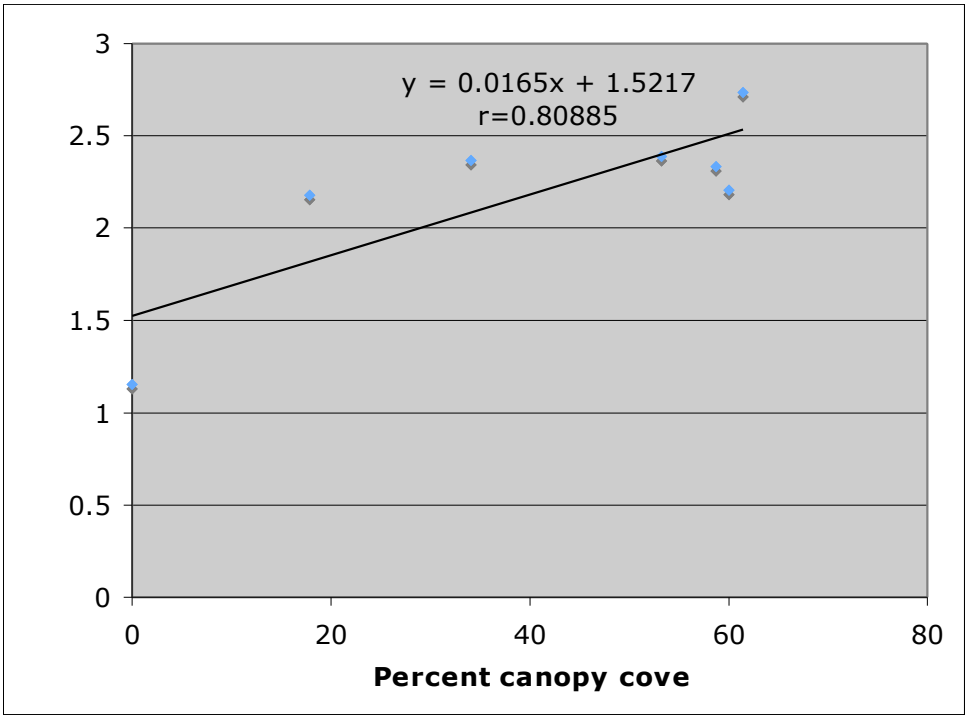
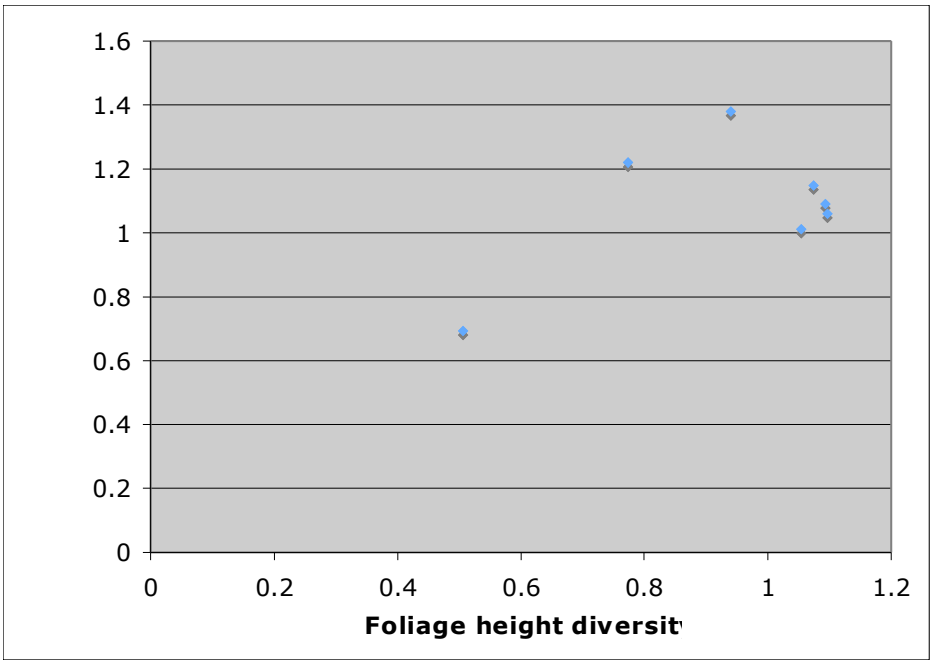


Figure 6. A. Migratory bird species diversity in relation to foliage height diversity in seven northern Michigan habitats. B. Migratory bird species diversity in relation to percent canopy cover in seven northern Michigan habitats.

A.



B.

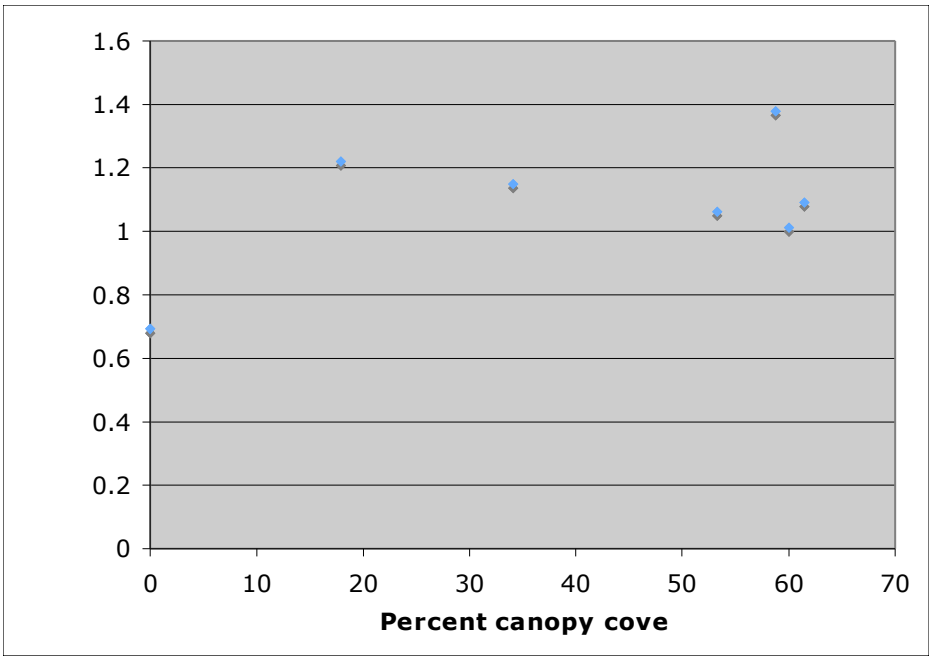


Figure 7. A. Year-round resident bird species diversity in relation to foliage height diversity in seven northern Michigan habitats. B. Year-round resident bird species diversity in relation to percent canopy cover in seven northern Michigan habitats.