Examining avian diversity with relation to snag density in wetlands and woodlands in the Great Lakes Region

BIOS 35502: Practicum in Field Biology

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Abstract

Snags (standing dead trees) are important in temperate ecosystems because they provide nesting and foraging habitat for cavity-nesting birds. Cavities excavated by these birds are subsequently used by many other wildlife species, including secondary-cavity nesting birds. Therefore maintaining natural snag density is important in order to maintain the natural diversity of forest ecosystems. This study focuses on the relationship between avian diversity and snag abundance in wetlands and unmanaged, second-growth mixed deciduous and coniferous forest stands at the University of Notre Dame Environmental Research Center. Point count call surveys analyzing avian species richness and abundance were undertaken during the period of 2 June and 12 July, 2011. Vegetation surveys were conducted within a 30 m radius around observation points counting the number of snags and live trees. Tree type (i.e. coniferous or deciduous) and snag dbh were also recorded. Species diversity did not differ between habitat type (p=0.1864), but analysis of variance suggests that snag density does have an effect on species diversity within sites although this relationship is not supported by regression analysis between number of snags per plot area and species diversity (p=0.0432). However, a relationship does exist between the proportion of coniferous snags and avian species diversity (p=0.0821). Therefore, future management decisions pertaining to timber harvesting and fire suppression practices should consider the use of coniferous snags by birds. Understanding the influence of snag density on bird communities is fundamental to developing harvest methods that ensure the conservation of forest birds.

Introduction

The management of forests for the timber industry and fire suppression drastically changes forest dynamics, especially the abundance of coarse woody debris (CWD) within a forest. CWD plays numerous roles in the functioning of a healthy forest and includes all dead wood, fallen logs, branches, large roots, and snags (standing dead trees). CWD provides an input of nutrients back into soils, long-term carbon storage, and essential habitat for various small mammals, amphibians, arthropods, and birds (Harmon *et al.* 1986). Therefore it is critical that CWD density is retained at levels found in pristine, unmanaged environments in order to maintain the natural diversity of forest ecosystems.

Cavity-nesting birds are important components of the avifauna in forests of the Great Lakes region, and primary cavity-nesting species are of special importance because they excavate cavities for nesting which are subsequently used by many other species of wildlife including secondary-cavity nesting bird species. Changes in number and characteristics of snags may affect the abundance of cavity-nesting birds because snags provide sites for nesting, roosting, and foraging (Mannan *et al.* 1980, Weikel and Hayes 1999). Legacy snags (large diameter snags from the previous stand) in young forests are especially important resources for cavity-nesting birds providing both nesting habitats (Mannan et al. 1980, Lundquist and Mariani 1991) and foraging substrates (Weikel and Hayes 1999). Understanding the influence of snag density on bird communities is fundamental to developing harvest methods that ensure the conservation of forest birds.

This study focuses on the relationship between avian diversity and snag abundance in wetlands and unmanaged, second-growth mixed deciduous and coniferous forest stands at the University of Notre Dame Environmental Research Center (UNDERC) located in the Upper Peninsula of Michigan. I predicted that snag densities would differ within and between habitat types and that bird diversity would vary accordingly such that the most diverse sites would be areas with high snag densities. Because other attributes of vegetation structure and composition are also known to be key factors in determining habitat selection by birds (MacArthur and MacArthur 1961), other factors such as canopy cover, proportion of live and dead trees, and the proportion of deciduous and coniferous trees were also analyzed in this study to help further explain observed patterns of bird diversity on the UNDERC property.

Materials and Methods

Site selection

Twelve sites were haphazardly selected at the UNDERC property to represent woodland and wetland habitats with varying snag densities. Upon first observation, three high density snag sites and three low snag density sites were selected for each habitat type for a total of six woodland and six wetland sites (Figure 1). The chosen sites were at least 250-m apart to guarantee that overlap of the point count areas did not occur. Characteristics of each site are described in Table 1. The woodland sites included both sugar maple woodlands and mixed conifer and deciduous stands. The six wetland sites included both bogs and fens with and without open water.

Point count call surveys

Avian richness and abundance were investigated through point count call surveys during the period of 2 June to 12 July, 2011 Birds were not surveyed in extreme weather, when wind or rain interfered with the audibility of bird calls, or when fog or rain impaired visibility. Surveys were conducted once each day within 4 hours after sunrise. This procedure yielded a total of 36 bird surveys: 9 for each habitat type and snag density, and 3 replicate surveys for each individual site.

The call surveys were conducted according to a standard point count method utilized in bird studies by the Breeding Biology Research and Monitoring Database at the University of Montana (Martin *et al.* 2007). Point counts involved an observer remaining at one location and recording all the birds seen or heard inside and outside of a 30 m radius circle within a 30 minute time period. Observation points were flagged so that point counts were taken from the same location within each plot. With the exception of a few wetland sites, each point was situated at least 30 m within the specific habitat. The species were written in the order of auditory observation and the number of individuals for each species was also recorded. Visual encounters were used to confirm call identification when species were within view from the observation point. To include only species actively using observation sites, flyovers were not included unless they landed within the plot area. A digital voice recorder was also utilized during each survey to record unknown calls which were later analyzed and identified to species.

Vegetation surveys

Tree trunks were counted within a 30 m radius surrounding each bird count point to quantify the proportion of tree types (i.e. coniferous or deciduous, live or snag) within each plot. Snags were identified as standing dead trees lacking green foliage. Snag diameter at breast height (dbh) was measured and used to calculate snag basal area. For both live trees and snags, I defined that each individual tree should stand at least 1.65m tall at an estimated angle >45 degrees, and >8cm dbh. Canopy cover was also calculated using a densiometer.

Statistical analysis

Jaccard's similarity index was used in a cluster analysis to compare similarities in species composition by site. The bird species diversity at each site was calculated using the Shannon-Weiner index of diversity. Shannon-Weiner is calculated as $H = -\sum p_i (\ln p_i)$ where p_i is the proportion of individuals which belong to the i^{th} species. This index provides a quantitative measure of the diversity of species in the total population at each particular site. This measure is conservative because abundance data was only noted when multiple birds of the same species were either within sight or calling back and forth.

Analysis of variance on number of snags was performed in Systat 13.0 (SPSS, INC., 2010) to determine if any significant differences occurred between habitat types. Regression analyses were performed to directly assess the relation between snag density and bird diversity, as well as the relationship between snag number and bird diversity. Regressions analyzing the relationship between bird diversity with snag basal area, cover, proportion of live trees, proportion of snags, proportion of deciduous and coniferous live trees, and the proportion of deciduous and coniferous snags were also performed. All data sets were tested for normality in Systat, and proportion data was transformed using arcsine square root transformation methods.

Results

A total of 191 birds, composed of 37 species, were observed during the course of this study (Appendix 1). The most common species observed was the ovenbird, followed by the yellow-bellied sapsucker. The ovenbird, yellow-bellied sapsucker, and blue jay were all present at the greatest number of sites (8), followed by the Nashville warbler (7). The mean number of individuals per survey at each site varied from 3 to 8.33, with a mean 5.31. Species richness per site ranged from 6 to 15 with a mean of 10.41. Bird species diversity ranged from 1.677 to 2.626, with an mean of 2.184 (Table 2).

Cluster analysis indicates that generally woodland locations were similar in species composition, and wetland locations were also similar in species composition (Table 3, Figure 2). Total snag density recorded as number of snags within each plot did not differ between wetland and woodland habitats ($F_{1,10}$ =0.1187, p=0.7376, Figure 2). Mean snag density within wetland habitats was 24 snags, and within woodland habitats it was 28.33 snags. Total number of snags did differ between high and low density snag sites ($F_{1,10}$=16.775, p=0.002, Figure 3). Mean snag density within high density sites was 101.5 snags, and within low density snag sites it was 93 snags. Species diversity, as calculated by the Shannon-Wiener index did not differ between habitats ($F_{1,10}$ =2.0124, p=0.1864, Figure 5). Mean species diversity within wetlands was 2.32, and within woodland mean species diversity was 2.05. Species diversity was significantly different between high and low density snag sites ($F_{1,10}$ =5.3581, p=0.0432, Figure 6). Mean species diversity within high density snag sites was 2.38, and within low density snag sites it was 1.99.

Regression analysis of basal area of snags versus species diversity did not show a relationship ($F_{1,10}$ =0.003485, R^2=0.0003, p=0.9541, Figure 7). Canopy cover versus species diversity also did not show a relationship ($F_{1,10}$ =0.988754, R^2=0.09, p=0.3435, Figure 8). A relationship also does not exist between number of snags and species diversity ($F_{1,10}$ =3.7348, R^2=0.2719, p=0.0821, Figure 9). Species diversity also did not show relationships with the proportion of live trees ($F_{1,10}$ =2.575181, R^2=0.2048, p=0.1396, Figure 10), proportion of dead trees ($F_{1,10}$ =2.575181, R^2=0.2048, p=0.1396, Figure 11), proportion of live deciduous trees ($F_{1,10}$ =2.8784, R^2=0.2235, p=0.1206, Figure 12), proportion of live coniferous trees ($F_{1,10}$ =2.8784, R^2=0.2235, p=0.1206, Figure 13), or the proportion of dead deciduous trees ($F_{1,10}$ =0.1986, R^2=0.0195, p=0.6653, Figure 14). However, species diversity does show a significant relationship with dead coniferous snags ($F_{1,10}$ =8.42062, R^2=0.4571, p=0.0158, Figure 15).

Discussion

Although Shannon-Wiener diversity indexes did not differ by habitat (Figure 5), cluster analysis (Figure 2) indicates that overall species composition varied between sites but species composition among woodland sites was generally more, and wetland sites were also generally more similar. However, two wetland sites have species composition more similar to the woodland sites than other wetland sites, but this can be mostly explained by wetland type. Site 9 is likely more similar to woodland species composition because it is a smaller bog surrounded by mixed coniferous and deciduous forest and all birds observed in this area visited this site from the surrounding forest edge. Site 10 is an almost completely open bog with standing water, no snags, and very few trees located within the plot area. It is therefore likely that most species observed here were simply visiting the site to take advantage of the open water from the surrounding forest edge.

Site 12 is primarily coniferous woodland that differs from both woodland and wetland habitats in its species composition (Figure 2). This is due to the fact that it was the sole location that two species, including the veery and white-breasted nuthatch, were observed during this study. White-breasted nuthatches likely prefer this site because they favor mature forests (Peterson 2010) and Site 12 is located at the north end of property on the edge of the Ottawa National Forest. The veery prefers willow and alder thickets along streams (Peterson 2010) and such habitat did border one side of this location because the northern area of property has been heavily modified by beaver activity.

Cavity nesting birds use a variety of decayed trees and snags for nesting, foraging, and roosting (Mannan *et al.* 1980). In prior studies, population densities of cavity nesters are positively correlated to snag density (Raphael and White 1984, Land *et al.* 1989, Lohr *et al.* 2002) and as a result, lower densities of cavity nesting birds have been identified as an important factor causing lower total bird density in managed forest stands (Nilsson 1979). Contrary to prior research and my original hypothesis however, this study did not find a relationship between bird diversity and snag density, either measured by basal area (Figure 7) or number of snags (Figure 9) although analysis of variance indicated that both snag density and calculated Shannon-Wiener diversity indexes were significantly different between high and low density snag sites (Figs. 4 & 6). It is not surprising that bird diversity in this region is not affected by snag basal area. Bird species that specifically require trees with larger basal area (>100 cm dbh) are likely not observed within my selected study sites because out of the twelve site studied, the largest snags found were <50 cm dbh. It has been observed that certain species do favor large snags over small snags when available (Mannan *et al.* 1980), including the pileated woodpecker which does occur on property and was observed within the course of this study. Therefore it would be interesting to further study individual snag use to further analyze the relationship between bird diversity and snag size.

The lack of apparent snag use could also be explained by prey availability and accessibility. In addition to providing nesting sites, birds also use snags for foraging. Snags harbor a different insect fauna than found in live trees and therefore type of insect prey availability in snags may have discouraged many birds, particularly birds that feed on insects found on foliage, from extensively using them (Franzeb 1978). Prey accessibility might also have limited snag use because feeding on insects living in snags requires morphological adaptations (Franzeb 1978).

The lack of a relationship between snag density and species diversity could also be the result of survey techniques. It is likely that more replicates per site could result in a significant relationship between number of snags and bird diversity, but due to a late project change and inclement weather during both research weeks I was only able to complete the minimum three replicates per observational site. The integrity of the first week of observations I made might also be decreased because I had no prior experience birding before the start of this study. Realizing this, I did attempt to repeat my initial five surveys so as to not include data that I was uncertain of in my analyses. Certain assumptions are made when performing point count call surveys which result in conservative observations of species diversity within sites because an observer can only be certain more than one individual of each species is located within a site if multiple birds were either within sight or calling back and forth. Therefore mist netting techniques would be able to obtain more accurate representations of abundance and bird species diversity within sites, enabling birds that do not call or sing to also be observed.

Avian diversity has also been found to correlate with other environmental factors including amount of foliage and vegetation structure (MacArthur and MacArthur 1961), and tree selection depends on food abundance, availability, and quality (Franzeb 1978). Foliage may be important for birds in that it protects them from predators and inclement weather conditions and shelters nest sites so that birds do not prefer using tree species or habitats associated with open vegetation (Franzreb 1978). I observed the foliage cover differed between woodland and wetland environments, with woodlands having generally more dense canopies than wetlands but I did not find a significant difference in species diversity between habitats nor a relationship between cover and species diversity (Figure 8). Although I did not find a significant relationship, it would be interesting to further study the relationship between foliage stratification and individual species use of foliage layers within a site, as well as tree species use comparing foliage volume between tree species.

Tree species selection has also been found to influence bird diversity, providing a variety of foraging habitats (Franzreb 1978, Wiekel and Hayes 1999). Deciduous trees are an important foraging substrate for species that forage primarily on live foliage (Franzreb 1978), and Schimpf and MacMahon (1985) found that arthropod density was higher in canopies of deciduous aspen forests than in canopies of coniferous forests. Wiekel and Hayes (1999) also suggest that the smaller passerine species, which include warblers and goldfinches, favor conifers because large leaf size of deciduous trees makes it difficult to perch on a branch and reach the outer portion of the leaves which harbor insects. Because most bird species observed within the course of this study are insectivorous, I therefore predicted that bird species diversity might vary not only with the proportion of snags, but that bird diversity might also show a relationship with varying proportions of deciduous and coniferous trees. It is interesting that the relationship between proportion of coniferous snags and species diversity was the only significant relationship found in this study, such that diversity appears to increase with increasing proportion of coniferous snags.

The significant relationship between coniferous snags and bird diversity could possibly be explained by the presence and quantity of dead branches found on coniferous snags which may influence foraging activity by cavity-nesting birds (Wiekel and Hayes 1999). Dead branches may be preferred foraging habitats because they have more sloughing bark which provides habitat for many arthropods including spiders, and therefore trees with more dead branches provide greater prey densities than snags with fewer dead branches (Holmes and Robinson 1981). Although number of branches was not recorded in this study, it was observed that coniferous snags tended to have a greater number of branches than deciduous snags. It should be noted that coniferous trees were the most common tree type observed within study sites and that the relationship of dead coniferous snags and species diversity might therefore be affected by availability. My study did not directly address selection of stand types or microhabitats within a stand for foraging by cavity-nesting birds, but my results suggest that selection may be occurring at these scales and therefore further study on tree species preferences is necessary.

In summary, this study did not find a relationship between avian species diversity and snag density on the UNDERC property. However, avian species diversity was found to be related to increasing proportion of coniferous snags. Therefore, future management decisions pertaining to timber harvesting and fire suppression practices should consider the use of coniferous snags by birds. The majority of coniferous snags should not be harvested because they serve several significant functions such as providing nesting and foraging sites for numerous cavity-nesting species. In order to understand factors affecting avian species diversity within the UNDERC property and ensure proper conservation of forest birds, further study is necessary to determine factors affecting stand type selection by cavity-nesting species.

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Table 1. Characteristics of study sites at the UNDERC property. Sites were surveyed during the period of June 2 to July 12, 2011.

	Type	Snag density	Description
Site 1	Wetland	High	Bog, emergent vegetation consisting primarily of tall grasses and speckled alder bushes. Lacking floating vegetation mat.
Site 2	Woodland	High	Mixed coniferous and deciduous woodland.
Site 3	Wetland	High	Open water bog with some emergent vegetation and multiple smaller floating vegetation mats.
Site 4	Woodland	Low	Deciduous woodland dominated primarily by aspens.
Site 5	Wetland	Low	Bog, with some open water and a large floating vegetation mat formed from sphagnum. No snags.
Site 6	Woodland	High	Mixed coniferous and deciduous woodland, high density course woody debris.
Site 7	Wetland	High	Tamarac bog associated with sphagnum mat, no open water.
Site 8	Woodland	Low	Sugar maple woodland.
Site 9	Wetland	Low	Small Tamarac bog dominated by sphagnum, lacking open water.
Site 10	Wetland	Low	Open water bog associated with tall emergent vegetation, lacking floating vegetation. No snags.
Site 11	Woodland	Low	Mixed woodland lacking dense understory and dominated primarily by spruce. Forest floor covered in sphagnum.
Site 12	Woodland	High	Mixed coniferous and deciduous woodland dominated primarily by pines.

Table 2. Shannon-Wiener diversity indexes for species composition within sites surveyed during the summer of 2011 at UNDERC. Site codes are as follows: Habitat type (W=woodland, B=wetland), snag density classification (H=high, L=low), and replicate number.

Site #	Code	Species (H')
Site 1	BH1	2.553454532
Site 2	WH1	2.394700406
Site 3	BH2	2.626164786
Site 4	WL1	1.846220219
Site 5	BL1	2.553237003
Site 6	WH2	1.859428815
Site 7	BH3	2.491493722
Site 8	WL2	1.676987774
Site 9	BL2	1.907283999
Site 10	BL3	1.798652206
Site 11	WL3	2.139085895
Site 12	WH3	2.36938212

Table 3. Jaccard's distance calculated from Jaccard's index in Cluster analysis. Sites were surveyed at UNDERC during the period of June 2 to July 12, 2011.

Clusters Joining		at Distance	No. of Members
BL2	WH1	0.571429	2
BH3	BH1	0.578947	2
BH3	BL1	0.600000	3
WL2	BL2	0.600000	3
WL3	WH2	0.615385	2
WL2	WL3	0.615385	5
WL1	WL2	0.636364	6
BH2	BH3	0.666667	4
BL3	WL1	0.692308	7
BH2	BL3	0.700000	11
WH3	BH2	0.700000	12

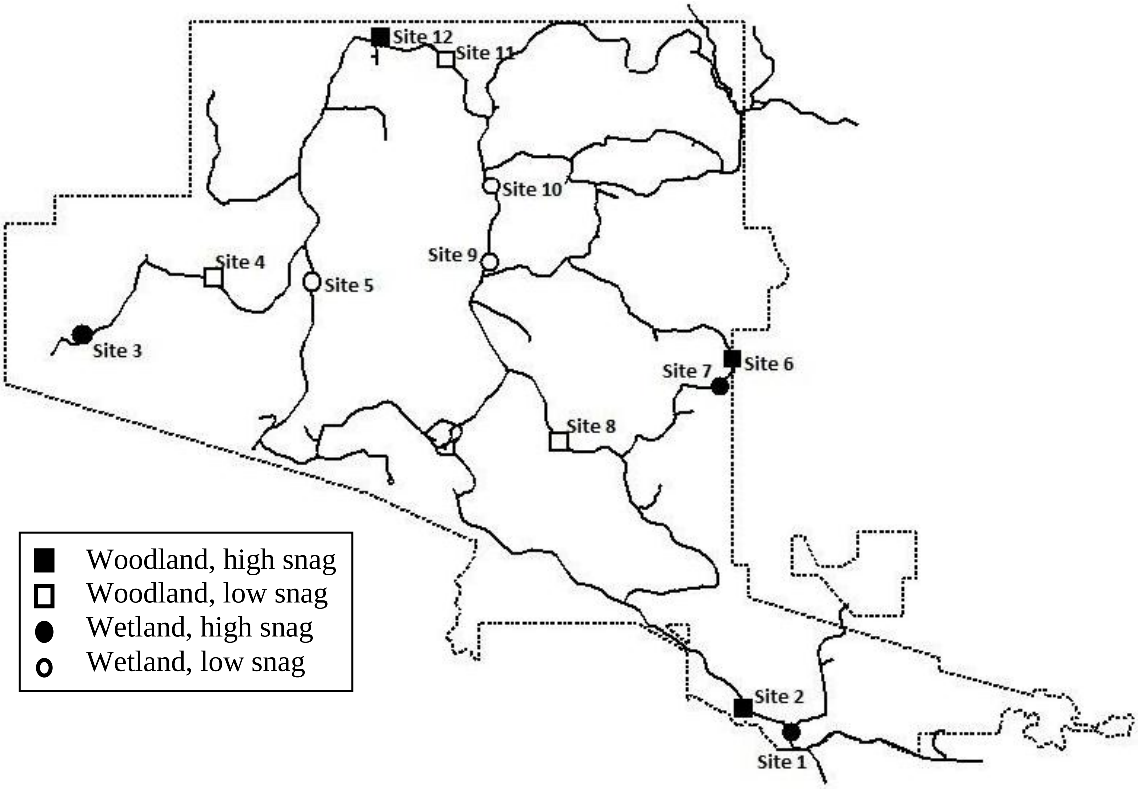

Figure 1. Study sites on UNDERC property surveyed during the summer of 2011. Black squares are high density snag woodlands, and white squares are low density snag woodlands. Black circles sites are high density snag wetlands, and white circles sites are low density snag wetlands.

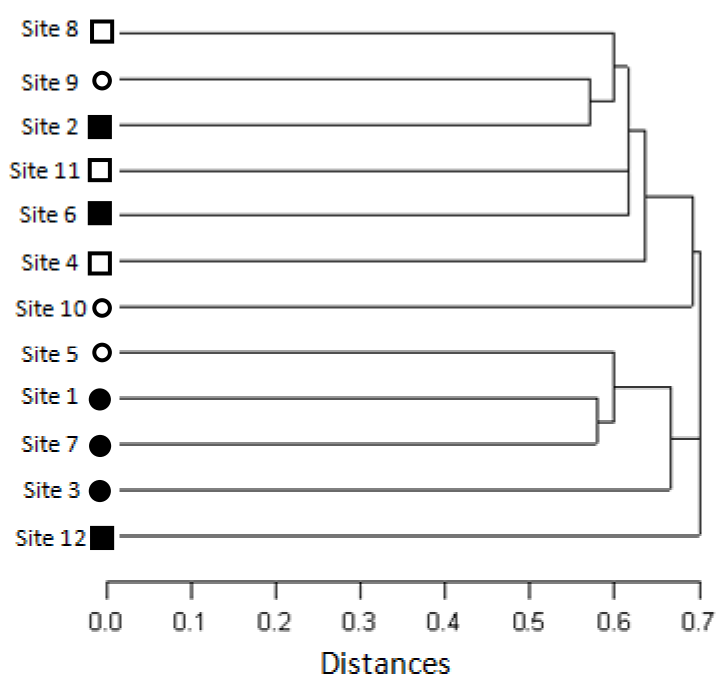

Figure 2. Cluster analysis based on distances calculated from Jaccard's index. Woodland sites are generally similar in species composition, and wetland sites are also similar with the exception of Site 9 and Site 10. Site 12 had two species observed at no other location on property. Sites were surveyed at UNDERC during the summer of 2011.

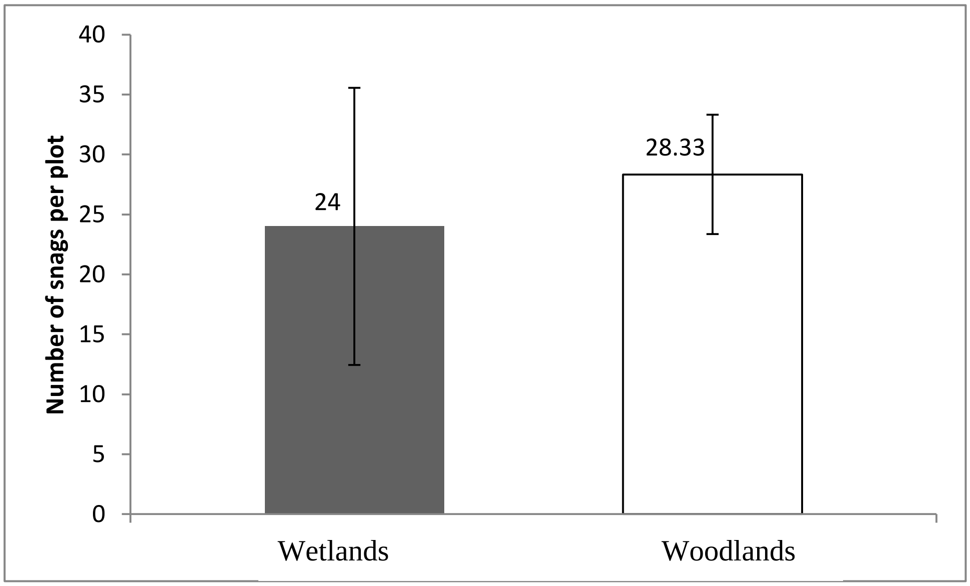

Figure 3. Mean number of snags between wetland and woodland sites (standard error shown). Sites were surveyed at UNDERC during the summer of 2011.

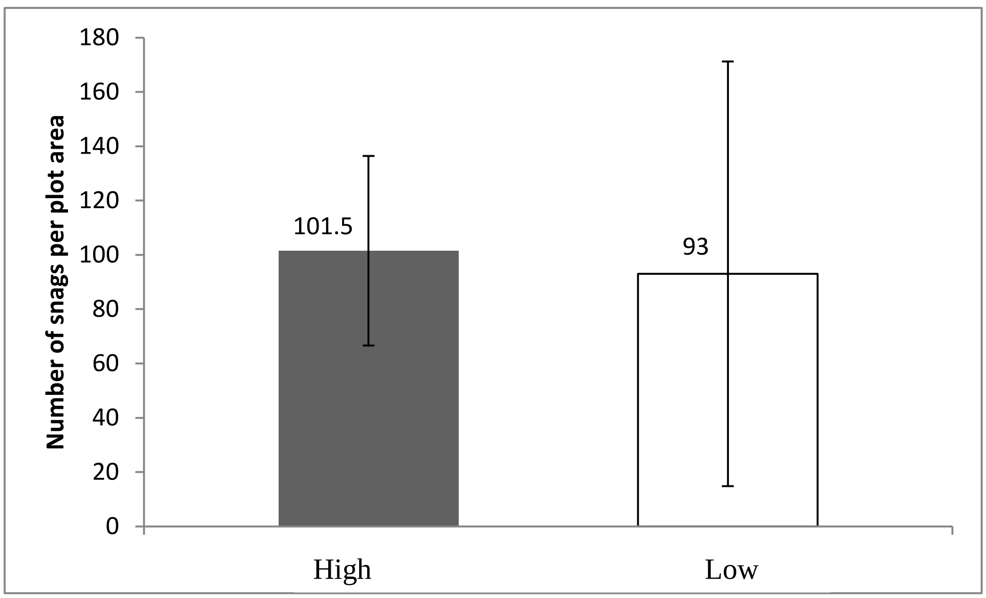

Figure 4. Mean number of snags between "high" and "low" density snag sites (standard error shown). Sites were surveyed at UNDERC during the summer of 2011.Large standard error likely results from the difficulty of sampling in wetland environments.

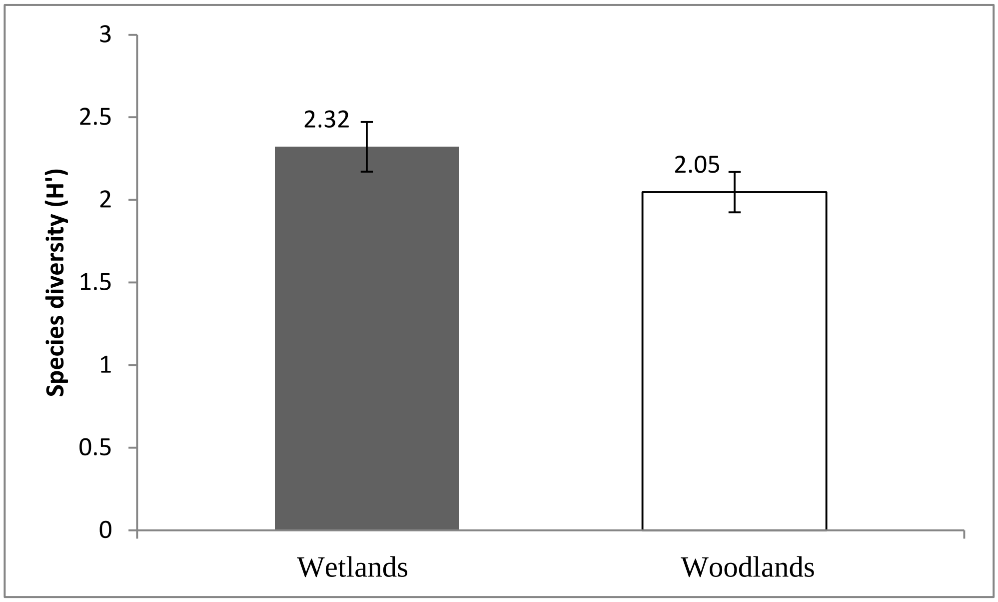

Figure 5. Mean Shannon-Wiener diversity between wetland and woodland sites (standard error shown). Sites were surveyed at UNDERC during the summer of 2011.

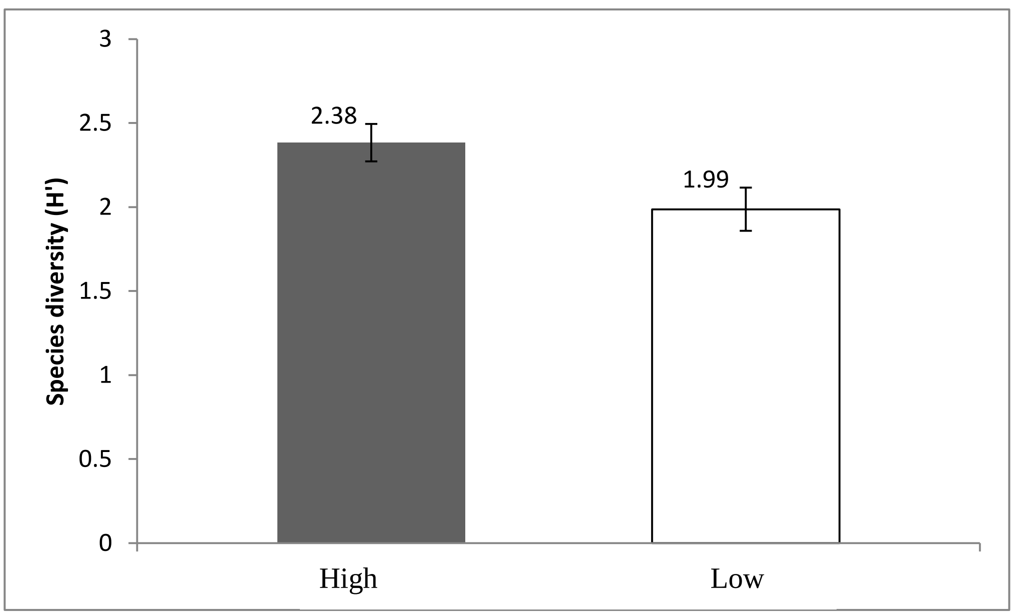

Figure 6. Mean Shannon-Wiener diversity between "high" and "low" density snag sites (standard error shown). Sites were surveyed at UNDERC during the summer of 2011.

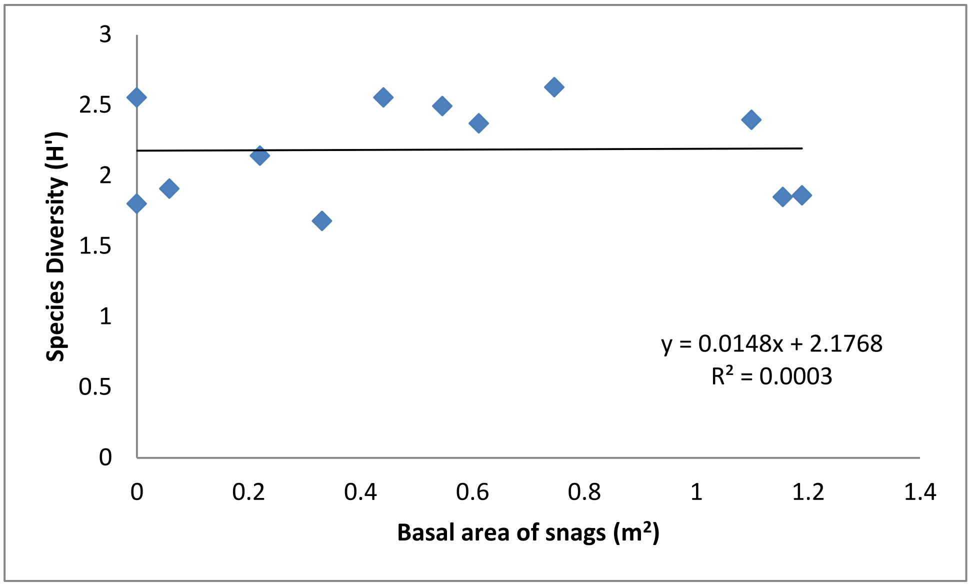

Figure 7. Relationship between basal area of snags (m^2) and Shannon-Wiener species diversity index (H') (p=0.9541). Sites were surveyed at UNDERC during the summer of 2011.

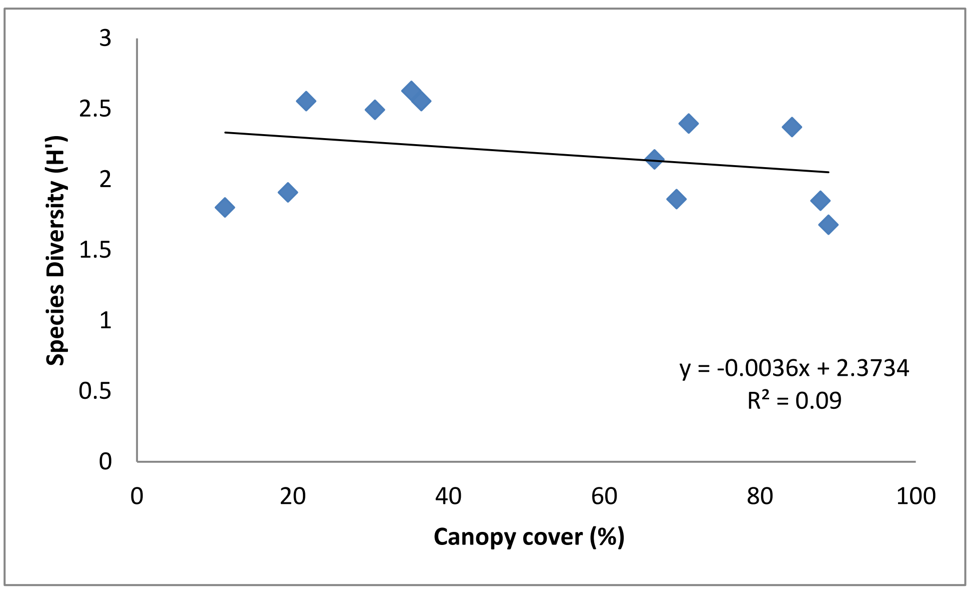

Figure 8. Relationship between canopy cover and Shannon-Wiener species diversity index (H') (p=0 .3435). Sites were surveyed at UNDERC during the summer of 2011.

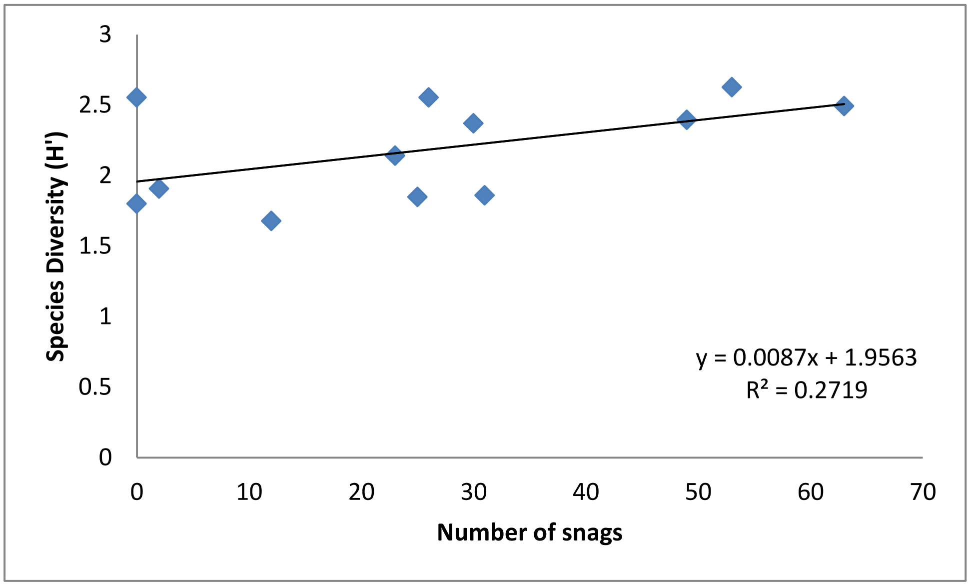

Figure 9. Relationship between snag number found in the plot area (30 m radius) and Shannon-Wiener species diversity index (H') (p=0.0821). Sites were surveyed at UNDERC during the summer of 2011.

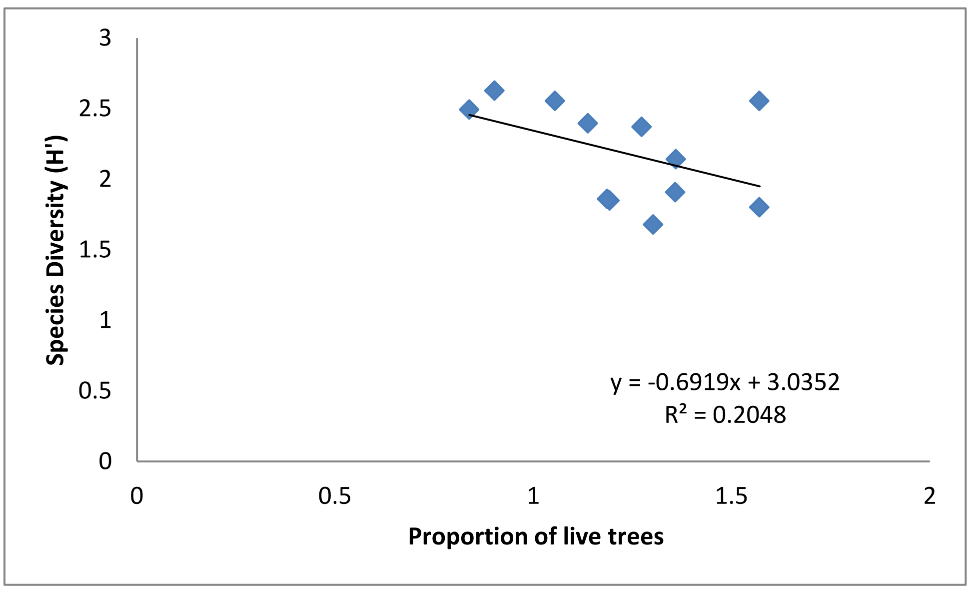

Figure 10. Relationship between proportion of live trees and Shannon-Wiener species diversity index (H') (p=0.1346). Sites were surveyed at UNDERC during the summer of 2011.

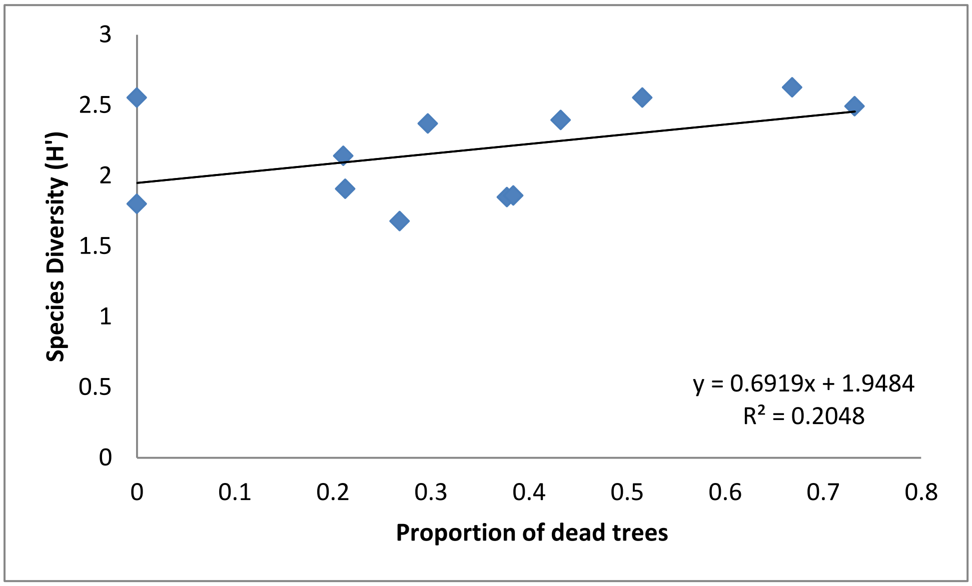

Figure 11. Relationship between proportion of dead trees and Shannon-Wiener species diversity index (H') (p=0.1396). Sites were surveyed at UNDERC during the summer of 2011.

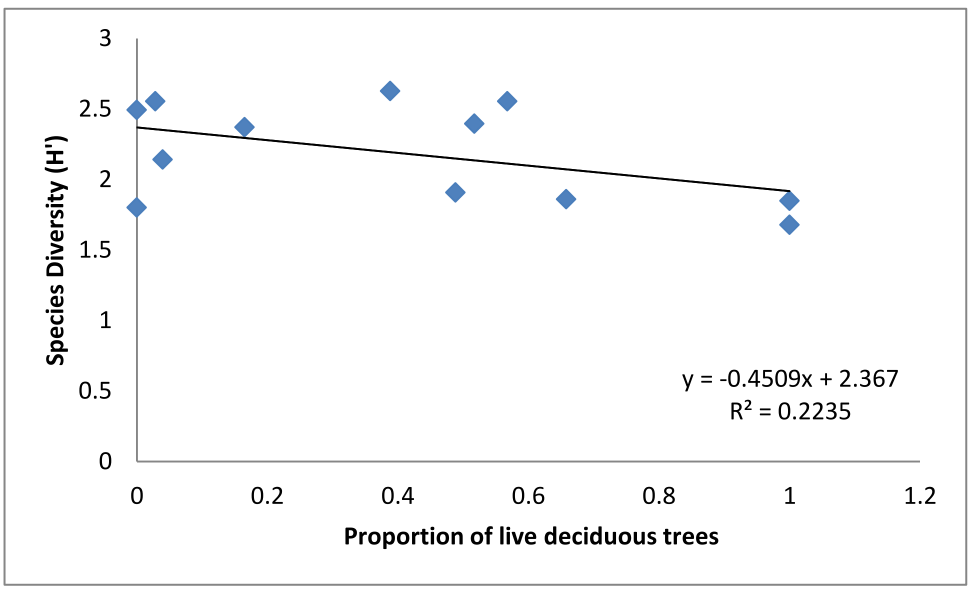

Figure 12. Relationship between proportion of live deciduous trees and Shannon-Wiener species diversity index (H') (p=0.1206). Sites were surveyed at UNDERC during the summer of 2011.

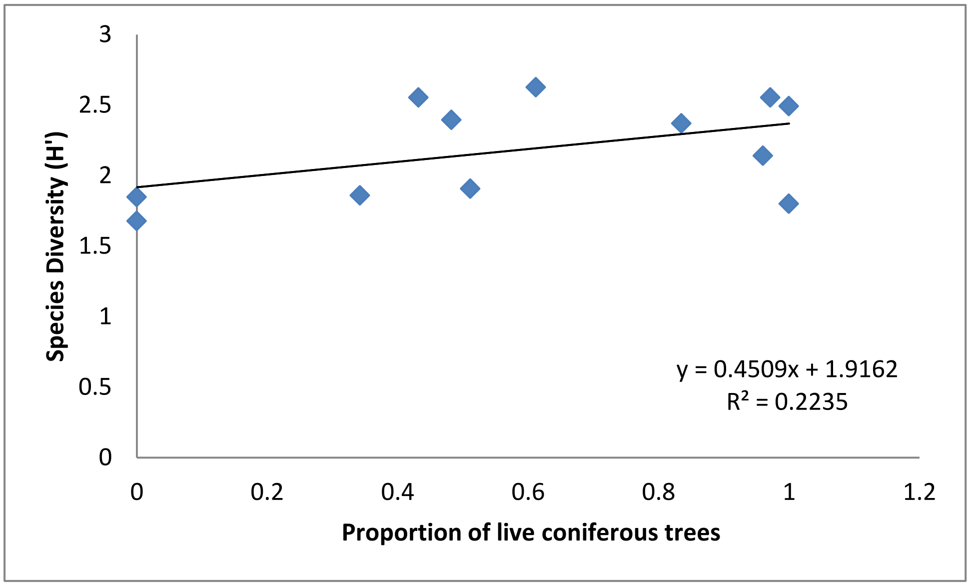

Figure 13. Relationship between proportion of live coniferous trees and Shannon-Wiener species diversity index (H') (p=0.1206). Sites were surveyed at UNDERC during the summer of 2011.

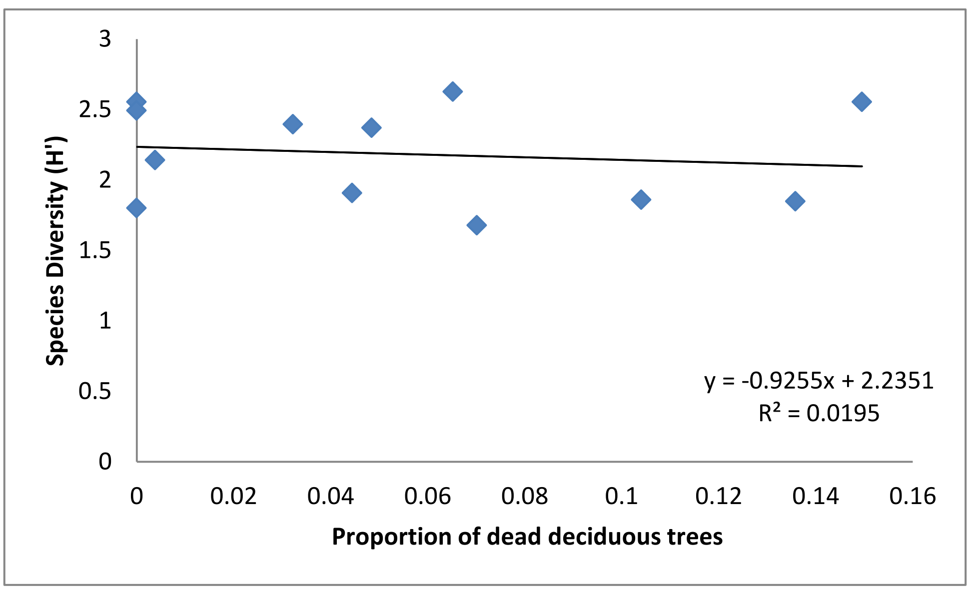

Figure 14. Relationship between proportion of dead deciduous trees and Shannon-Wiener species diversity index (H') (p=0.6653). Sites were surveyed at UNDERC during the summer of 2011.

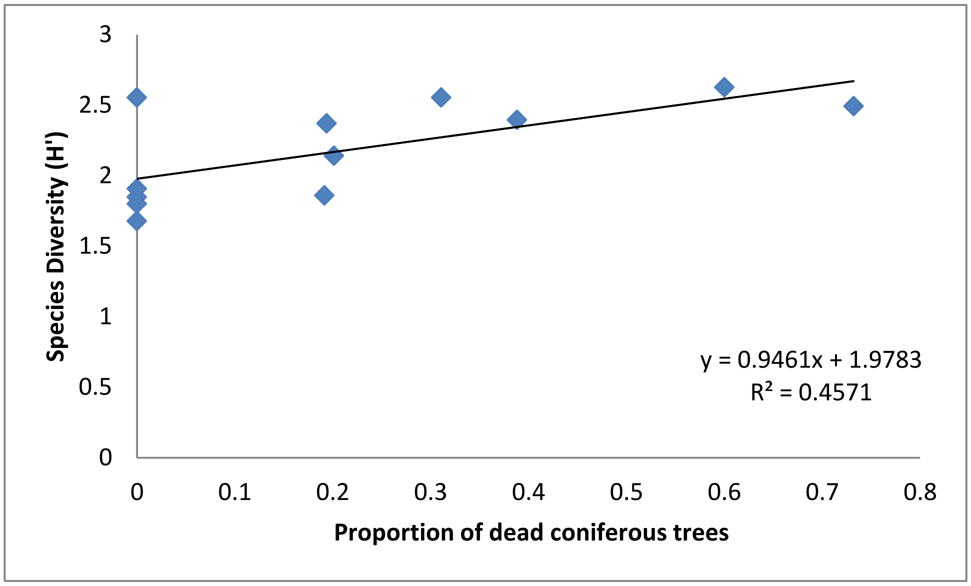

Figure 15. Relationship between proportion of dead coniferous trees and Shannon-Wiener species diversity index (H') (p=0.0158). Sites were surveyed at UNDERC during the summer of 2011.

APPENDIX

Table A-1. Abundance and distribution of observed bird species at the UNDERC property between 2 June and 12 July, 2011. Codes follow English names prepared by the Institute for Bird Populations.

Species	Total No. of Individuals Observed	Total No. of Sites Where Present
NAWA	9	7
NOPA	7	4
YWAR	5	5
CMWA	7	5
YRWA	3	3
BTNW	5	3
BAWW	5	4
AMRE	3	2
OVEN	22	8
COYE	6	3
RBGR	1	1
CHSP	5	4
SOSP	6	4
SWSP	11	5
WTSP	10	4
RWBL	3	3
COGR	5	2
AMGO	2	2
RTHU	3	2
BEKI	3	2
YBSA	14	8
NOFL	1	1
PIWO	3	3
OSFL	1	1
ALFL	2	2
LEFL	2	2
EAKI	5	3
WAVI	1	1
REVI	9	6
BLJA	8	8
VEER	1	1
HETH	5	4
AMRO	3	3
WOTH	2	1
CEDW	10	5
WBNU	1	1
HAWO	2	2

Table A-2. Count data on the number of live trees and snags by tree type within a 30 m radius plot area from each observation site on the UNDERC property. Sites were surveyed at UNDERC during the summer of 2011.

	Live trees		**Snags**	
Site	**Coniferous**	**Deciduous**	**Coniferous**	**Deciduous**
1	35	46	10	16
2	111	119	40	9
3	52	33	44	9
4	0	159	0	25
5	34	1	0	0
6	65	125	8	23
7	78	0	63	0
8	0	159	0	12
9	22	21	0	2
10	19	0	0	0
11	483	20	21	2
12	268	53	13	17