COMMUNITY COMPOSITION AND INFLUENCE OF FOREST STRUCTURE ON BIRDS IN THE EVERGREEN STATE COLLEGE FOREST RESERVE

by

Jora Rehm-Lorber

A Thesis
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
March 2009

This Thesis for the Master of Environmental Studies Degree

by

Jora Rehm-Lorber

has been approved for

The Evergreen State College

by

Alison Styring, PhD
Member of the Faculty

Dylan Fischer, PhD
Member of the Faculty

Joan C. Hagar, PhD
Research Wildlife Biologist, USGS

Date

ABSTRACT

Community Composition and Influence of Forest Structure on Birds in The Evergreen State College Forest Reserve

Jora Rehm-Lorber

The temperate rainforests of the Pacific Northwest support the highest abundances of birds of any coniferous forest system in North America. Birds are indicators of ecological health and provide a number of ecosystem services such as pollinating plants, dispersing seeds and controlling insect and rodent populations. Many birds in the Pacific Northwest are experiencing dramatic declines, especially within lowland temperate rainforests which are under development pressure and may face ecological changes with a warming climate. The objective of this thesis is to lay the foundation for avian science endeavors at the Evergreen State College (TESC). In this study I describe baseline bird population findings and their relationships to forest structure and vegetation attributes measured in 44 permanent forest plots. TESC bird abundance was estimated at 11.86 birds/ha representing 55 different species. Using community ordination methods, significant differences were found in avian community structure among forest types. Comparison of regression models suggested deciduous overstory was the best predictor of overall bird abundance. Indicator species analysis revealed species specific examples in relation to forest type. Snag decay stage diversity was negatively related to avian diversity, but was not affected by attributes of DWD. Sapling biomass had a positive relationship with avian diversity, but not abundance. While these findings are supported with data from only one breeding season, long-term data collection will help to test and evaluate the best predictors of bird abundance and diversity in this ecosystem. Also described are the necessary field protocols, tools and research considerations for the newly created Evergreen Avian Monitoring Program (EAMP) to continue long-term monitoring efforts.

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Acknowledgements

This work would not have been possible without the collaboration and assistance of many students and faculty of the Evergreen State College. I thank the undergraduate programs of Introduction to Environmental Studies: Land (2006/07), Temperate Rainforests (2007), and Field Ecology (2008). Various members of the Evergreen Ecosystem Ecology (E3) lab assisted in data collection in the summer of 2008 and discussed chapter drafts. I am indebted to the patience, humor and hard work of the 2008 EEON lab manager, Justin Kirsch. Thesis advisors Alison Styring, Dylan Fischer and Joan Hagar gave their invaluable input and expertise in the many disciplines this thesis covers. What intended to be a 2 year masters program turned into nearly 3 and I am grateful to my family and friends for their support, encouragement and patience. Funding for the Evergreen Ecological Observation Network was provided by The Evergreen State College.

Chapter One

Avian Community Composition and Abundance Estimates at the Evergreen State College

Abstract

The temperate rain forests of the Pacific Northwest support the highest abundances of birds of any coniferous forest system in North America, however many of these bird species are experiencing dramatic declines. The objective of this thesis is to lay the foundation for avian science endeavors at the Evergreen State College (TESC) stemming from the creation of the Evergreen Ecological Observation Network (EEON) which monitors the campus's temperate rainforest ecosystem. This chapter details landbird conservation programs and baseline population findings for the Evergreen Avian Monitoring Program (EAMP). In the spring and summer of 2008 I completed the first comprehensive bird community study at the college. I estimated overall and species specific densities for twelve common forest breeders, and compiled a complete year-round species list and a list of confirmed breeding species from observations throughout the 2008 breeding season. These data serve as baseline information for the monitoring program and as an educational tool for local ornithology at the college and for the surrounding community. Overall, TESC bird density was estimated at 11.86 birds/ha for 55 detected species. Density estimates, diversity indices and species area curves will guide the work of future avian monitoring and student research. Over the long term, this scientific data will inform the college's forest management objectives as the student body continues to grow and land use decisions influence the forest reserve system.

1. 1 Introduction

1.11 The Evergreen Ecological Observation Network

The 1,033-acre second-growth rainforest surrounding the developed campus of the Evergreen State College (TESC) is one of the largest in the south Puget Sound (Hall et al. 1976). Other large forested areas with lowland temperate rainforests (i.e. Capitol State Forest) are present but consist of patchwork landscapes and are managed for timber and other resources by private and state entities (Franklin et al. 2002). Since the acquisition of land by the college in 1968, the forest has been left largely unmanaged aside from routine trail and road maintenance. A recently revised campus master plan addresses land use principles for the college and emphasizes the role of its natural areas to be preserved for recreation, cultural and educational development (Zimmer Gunsul Frasca Architects 2008). The forested area acquired by the college is often referred to as a "reserve" because it represents a forested island in an increasingly urbanized area (Figure 1). Native habitats of coastal and lowland areas are heavily encroached upon by urbanization and as the Puget Sound experiences rapid population growth, protected mature and intact forests within the basin will provide vital wildlife habitat (Rich et al. 2004). Several large development companies have purchased existing areas of forested land adjacent to college property in the last ten years and completed planned residential communities (Figure 1). This suburban development has further reduced surrounding forest habitat and increased the biological and cultural value of TESC's undeveloped areas.

The college's forest reserve has existed as a unique field site in some capacity since the 1970's, providing students and faculty with a living laboratory right outside the door. Other Pacific Northwest field sites are outside of the Puget Sound basin, often far inland and at elevations well above sea level. Additionally, many lowland temperate forests in the Pacific Northwest are young coniferous forests, managed in 50 year rotations (Altman and Hagar 2007), making an unmanaged 80 year old lowland forest increasingly rare and worthy of study.

Many students and faculty with a variety of educational and professional backgrounds see the forest as an excellent place to incorporate environmental and sustainable awareness into their curriculum. The interdisciplinary nature inherent to the college's philosophy has allowed for students to spend time in the forest through the mediums of spiritual and cultural expression, art, humanities and science. Aside from the positive affect the Evergreen forest has had on components of core level and introductory interdisciplinary courses, field based work in the biological sciences on campus is enhanced and continues to flourish as a result of the campus's forest system (Greenberg and Hartley 1998, Kennedy and Quinn 2001, Kazakova et al. 2007, International Canopy Network 2008, Zimmer Gunsul Frasca Architects 2008).

Faculty in the biological sciences at the college saw the potential to create a long term research network that would allow the college and collaborators to track temporal changes occurring within the forest ecosystem during a time of climatic change. Through a grant from the college, a team of faculty created the Evergreen Ecological Observation Network (EEON) in 2005. Since its inception, the network has supported the work of dozens of independent student projects, as well as faculty research and has served as a learning tool for a variety of programs. Establishment of the network has been a collaborative process involving many TESC students of all educational levels and several dedicated individuals. After the establishment of 52 gridded study plots, a subset of 10 was intensively studied by undergraduates whom collected data on forest structure and vegetation. Over the last two years student research projects involving aspects of forest ecology have occurred in these plots while concurrent field work collected baseline data on 37 additional plots. Today EEON consists of 47 working plots with complete forest structure data on live trees, snags, downed-woody debris (DWD) and understory vegetation.

The incorporation of other scientific disciplines into EEON was an important component emphasized during the planning stages. The network was designed with the college's tradition of interdisciplinary study in mind and intends to support and facilitate research and monitoring from a variety of disciplines. This collaboration will assist in our understanding of ecological communities and processes, and expose students to many disciplines outside their field of study. The objective of my study is to bridge the disciplines of forest ecology and wildlife science in order to describe the status and distribution of birds living in the forest reserve in relation to their habitat. In this chapter I provide the first abundance estimates of TESC's forest birds and describe the structure and composition of the bird community. Birds were chosen as study subjects here because they are easily observable, well studied and charismatic. Additionally, many Pacific Northwest forest bird species are experiencing dramatic declines (Marzluff and Sallabanks 1998, Donovan et al. 2002, Rich et al. 2004). This study will provide baseline data for the creation of an avian monitoring program linked to EEON; a viable and logical progression in developing the network's breadth and scope.

1.12 Overview on monitoring bird populations

Many bird species serve as indicators of habitat quality, with changes in their populations linked to changes in ecological health (Marzluff and Sallabanks 1998, Zack 2002, Rich et al. 2004). Understanding bird population dynamics is critical to conservation efforts (Thomas 1996). Conservation of forest birds is important because these species provide many ecological services ranging from controlling insect and rodent populations to pollinating plants and dispersing seeds (Gill 2006). Birds that primarily breed in forests face threats to reproduction success and increases in mortality, both of which are now widely accepted in the scientific world to be linked to habitat loss (Marzluff and Sallabanks 1998, Donovan et al. 2002, Norris and Pain 2002, Plummer 2002, Ruth et al. 2003). Migratory birds are particularly susceptible to habitat loss because they require a diverse and geographically large range of habitats at different stages in their life (Robbins et al. 1989, Donovan et al. 2002). For example, a Neotropical migrant breeder of the temperate rainforest may require a multi-layered forest canopy for breeding, dense riparian zones during migration, and dry deciduous woodland for wintering, all of which are experiencing their own habitat degradation.

The temperate rainforests of the Pacific Northwest support the highest abundances of birds of any coniferous forest system in North America (Altman 1999). Although these forests support a large number of birds, populations are changing due to many species experiencing dramatic declines (Sharp 1996, Plummer 2002, Sauer et al. 2006). Another 1.4 million people are expected in Puget Sound by the year 2020 and with them additional urban development (Lombard 2006). With increasing habitat loss throughout the Puget Sound basin, there is an urgent need for monitoring programs to track changes in wildlife populations and other ecological changes through time (Lombard 2006). The creation of the Evergreen Avian Monitoring Program (EAMP) as part of EEON will represent one of the only long-term monitoring efforts for landbirds of lowland temperate rainforests outside of the national park system (Siegel et al. 2004, Wilkerson et al. 2005). The protected lands owned by TESC coupled with the stability of ongoing scientific research at the college provide an excellent opportunity to establish a multifaceted monitoring program combining the essential components utilized by other well known monitoring programs around the country and standardized to achieve comparisons among locations and projects (Ralph et al. 1995).

One of the largest and most comprehensive of these monitoring programs is the North American Breeding Bird Survey (BBS). Currently the BBS comprises over 4,100 routes across North America and provides estimates of population trends for 420 bird species (Sauer et al. 2008). Despite their widespread coverage, BBS routes occur only along roads and collect only relative abundance data to generate population trends. Estimates of population size or absolute abundance estimates are not possible with BBS population indices data. In general, these population indices are seldom comparable among species and monitoring programs. Thomas (1996) suggests BBS methods can be applied in areas with more intensive studies underway, in an attempt to quantify observer differences and estimate variations in detectability. Using methods comparable to the BBS, EAMP will eventually allow for a more detailed description of bird populations in the south Puget Sound area with absolute abundance estimates related to many habitat characteristics.

Another major player in the development of landbird conservation plans for North America was the creation of Partners in Flight (PIF) in 1990. The partnership, which represents private, non-profit and public organizations aims to a) help at -risk species before they become imperiled, stemming from the view that conservation implementation is most effective before populations reach crisis levels, b) keep common birds common by monitoring populations, and c) achieve bird conservation objectives by advocating for “combining, coordinating and increasing” voluntary resources (Rosenberg 2004).

In 2004, landbird conservation priorities were synthesized in the Partners in Flight North American Landbird Conservation Plan (Rich et al. 2004). State reports written by PIF regional coordinators outline each state's priority species, their population objectives and numerical targets, and divide population estimates for each species into Bird Conservation Regions (BCR's) and primary breeding habitats.

Individual species assessments are based on the PIF North American Species Assessment Database which utilizes BBS data. Because BBS methodologies are designed to cover large areas with limited resources, BBS trends for many species are lacking or have low precision (Rich et al. 2004). A very limited amount of alternative data exists to supplement BBS routes and therefore many species are lacking population trend (PT) scores (a score of 1-5 from large population increases to large population declines).

The future work of EAMP may assist updates to PIF state documents, including the implementation of new population trend scores. EAMP monitoring protocols and research plans will aim to augment the power of the BBS and work to test hypotheses about causes of population change in priority species. In the longer term, EAMP may provide comparative data on the mechanisms influencing landbird responses to conservation implementation. Priority species and population objectives for birds detected during EAMP 2008 surveys are described in appendix D.

Once established, EAMP can mirror the work of other nationally recognized organizations with large scale and long term monitoring efforts currently underway, with a focus on birds of the Puget Sound lowland rainforests. By following the standard protocols of other monitoring programs, EAMP can engage in data sharing to link bird populations here on campus to a larger continental or global context. Increasingly, avian biologists and conservationists are emphasizing the imperativeness of collaborative science when attempting to understand declines in bird populations. Data sharing networks such as the Avian Knowledge Network (ANK) were created to allow scientists and citizens alike to access and provide information about bird populations (Avian Knowledge Network 2008). Eventually EAMP will have its own AKN node with public access available to other monitoring programs, organizations, students and citizens.

The objective of this thesis is to lay the foundation for avian science endeavors at the Evergreen State College (TESC) stemming from the creation of the Evergreen Ecological Observation Network (EEON). In this chapter I present the first comprehensive data on breeding bird species of the TESC forest reserve and generate reliable density estimates for the most common breeding species using distance methodologies. To provide a context and stimulate further discussion and research, I present these results in relation to conservation objectives and compare these first year estimates to other density data from Pacific Northwest rainforests in Western Washington.

1.2 Methods

1.21 Study site

The Evergreen State College lies southwest of Olympia, WA, Thurston County (approx. 47°04’N, 122°58’W). The area receives an average of 130 cm of precipitation per year, with nearly half the days in a year receiving substantial rainfall (Barrier and Froyalde 1999). Average annual temperatures range from 3.9 to 15.6 degrees Celsius. The campus is relatively flat with near sea level elevation (highest point is 74 meters). The forest reserve is representative of a coastal temperate rainforest in the Western Hemlock Zone, characterized by high productivity and complex forest structure (Franklin and Dyress 1973). The forest itself is a mosaic of dominant stands of Douglas fir

(*Pseudotsuga menziesii*), codominant mixed hardwood and conifer stands, with red alder (*Alnus rubus*), big-leaf maple (*Acer macrophyllum*) and scattered cottonwood (*Populus trichocarpa*), nearly pure stands of red alder in early succession areas and wetter conifer areas consisting of western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) associations (Figure 2). Douglas-fir forests, which dominate western Oregon and Washington, support the highest bird densities of any coniferous forest systems in North America (Wiens 1975). They also have been some of the most intensively managed forests in the world, and are home to several high profile endangered species such as the Northern Spotted Owl and Marbled Murrelet (Rich et al. 2004).

The topography of campus is generally flat with the highest elevation at 74 meters above sea level. The landscape is characterized by gentle slopes bisected by five steep-sloped, short (mostly ephemeral) streams with headwaters within, or just outside of the reserve, and steep bluffs along the waterfront of Eld Inlet. My work took advantage of a network of 10-meter radius permanent plots established in 2006 using a systematic random grid with plots 250 meters apart across the reserve (http://academic.evergreen.edu/projects/EEON).

1.22 Data collection

I conducted five minute variable circular plot (VCP) point counts from 23 April to 22 June 2008 at 47 permanent plots. I visited each plot once in the early season and once in the late season to equally sample early nesting resident species and late nesting migratory species. I recorded the horizontal distance to the nearest meter for each bird detected with the aide of laser rangefinders and flagging. I recorded all birds seen and heard, excluding birds that flew overhead and did not appear to be utilizing the habitat.

I conducted a pilot study from 17 March to 22 April 2008 using several VCP analysis methods to assess forest songbird abundances (Reynolds et al. 1980, Ralph et al. 1995, Bibby et al. 2000). The pilot study offered an opportunity to practice point count surveys, initially locate plots to save time during actual surveys, and identify the best available protocol based on field work effort balanced with statistical power. I conducted multiple surveys at each of the 47 permanent plots using a) the methods of surveys conducted in June of 2006 which utilized 5 continuous 1 minute counts to increase the number of sample units, and b) method of one 5 minute count divided into the first 3 minutes and the last 2 to allow for comparisons of data to the Breeding Bird Survey (BBS). In the first 3 minutes all birds heard and seen are recorded and in the last 2 minutes only new individuals not previously heard or seen are recorded. The 2008 pilot data was entered into Distance 5.0 (Thomas et al. 2005) to draw statistical comparisons of avian abundance estimates for each of the above methods (see 1.24 statistical analysis). Interestingly, combined three and two minute counts yielded slightly lower AIC values and better model fits with truncation to 150 meters. Given the increased workload of conducting one minute counts and the skill required to record all bird heard and seen within a very short time period, five minute counts were selected for this study. In the future other students may wish to try different methods in collaboration with five minute counts, such as double sampling (Bart and Earnst 2002, Collins 2007) and double observer methodologies (Forcey et al. 2006, Kissling and Garton 2006) .

Each 5 minute survey was separated into 3 and 2 minute periods, beginning within 30 minutes of local sunrise and concluding 3 hours after sunrise (Ralph et al. 1995). Separating observations into the first three minutes and last two minutes improves comparability with BBS routes which utilize three minute counts. All other bird species not associated with the habitat were listed separately. Environmental data including cloud cover, temperature, wind, precipitation and noise level (scale of 0-3) were also recorded. Surveys were suspended due to high winds (>10mph) or precipitation which penetrated the forest canopy. These environmental variables influence an observer's ability to detect birds and can also be tracked over the long-term to reveal potential causes influencing bird populations. The level of road or construction noise can influence detection rates because detections in dense forested habitats are generally greater than 90% aural (Ralph et al. 1995).

1.23 Statistical analysis

I estimated avian abundances using program DISTANCE (Thomas et al. 2005)[1]. The program uses maximum likelihood to calculate a detection function based on distance from the observer and uses this function to estimate densities per hectare (Buckland et al. 2001). I used the half normal cosine model to estimate densities from 94 point counts at 47 plots. I used a combination of three criteria to select a final model. The Akaike information criterion (AIC) is a method for determining model fit, where lower AIC values yield better fits. I also used goodness of fit and Kolmogorov-Smirnov tests which determine if the modeled and real datasets differ significantly. For each model, I stratified by species and habitat to estimate species specific and pooled avian densities in

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[1] Among the wide array of methods for monitoring avian populations two prominent methodological approaches are widely used. The first is the use of population indices generated by fixed radius point counts in which all birds are recorded that fall within a certain radius (usual 50 meters in forested habitats) around the observer regardless of the bird's actual distance (Hutto et al. 1986). The statistical analyses of relative abundance data has historically yielded significantly different population trends for the same species (Link et al. 1994, Sauer et al. 1994) and there is currently no consensus on what statistical methodologies best model actual population trends (Thomas 1996). Distance sampling was developed in response to the widespread use of population indices. In distance sampling the observer records the distance to each bird detected with the central premise that birds are harder to detect the further they are from the observer. Actual observations are then modeled to account for individuals present but not detected during a survey (Thompson 2002). Distance sampling has become the standard in much ornithological research and increasingly, monitoring projects (Ellingson and Lukacs 2003, Siegel et al. 2004, Wilkerson et al. 2005). The debate on whether to use indices or distance methods continues with many alternative approaches proposed in recent years to account for observer and measurement biases and address the issues of conflicting results in population trends and management strategies (Nichols et al. 2000, Bart and Earst 2002, Bart et al. 2004, Forcey et al. 2006, Kissling and Garton 2006, Collins 2007). In this study I use distance methods as a logical starting point, with data collection allowing for transformation to index methods. This method also allows for the incorporation of other methodologies (i.e. double-observer and double-sampling) to be tested by EAMP in the future.

order to extrapolate habitat differences. Forest types were ascertained through a student research project which utilized aerial photography and GIS technology (Greenberg and Hartley 1998). Greenberg and Hartley's (1998) original work consisted of nine distinct forest types (Figure 2). I simplified the forest typing classification system used in 1998 to help elucidate any possible differences in habitat selection for avian species detected in these habitats. I separated plots into either a) Douglas-fir, b) maple, c) alder, d) mixed conifer, e) mixed conifer/deciduous, f) mixed deciduous. To explore avian community composition I calculated species richness, species evenness and Shannon's and Simpson's diversity indices using program PCORD (McCune and Mefford 1999).

1.3 Results

1.31 Abundance estimates

During surveys I detected 2013 individual birds of 55 species (Appendix A). Densities were estimated for 12 species with over 60 detections (Table 1) based on recommendations by (Buckland et al. 2001). In order to ascertain reasonable estimates of abundance with good model fits, distance sampling protocols recommend a relatively high number of detections per a species. This means only common and easily detectable species are considered here.

Five of the 12 species with density estimates are Neotropical migrants, whom come to our forest each summer to breed and return each fall to various locations throughout the Caribbean and central America. These species include Pacific-slope Flycatcher (*Empidonax difficilis)*, Swainson's Thrush *(Catharus ustulatus)*, Black-throated Gray Warbler *(Dendroica nigrescens)*, Wilson's Warbler (*Wilsonia pusilla)*, and Western Tanager (*Piranga ludoviciana)* (Table 1). Two other species with density estimates were American Robin (*Turdus migratorius)* and Purple Finch (*Carpodacus* *purpureus)* which exhibit food driven migration patterns, moving to different areas of Washington throughout the year (Wootton 1996, Sallabanks and James 1999). The remaining five, Chestnut-backed Chickadee (*Poecile rufescens)*, Red-breasted Nuthatch (*Sitta Canadensis)*, Winter Wren (*Troglodytes troglodytes)*, Spotted Towhee (*Pipilo maculates),* and Song Sparrow (*Melospiza melodia*) are resident species that spend their entire lives in a local area. Resident species which maintain small territories and are easily observable make good candidates for year round and over-wintering monitoring efforts (see chapter three).

I qualitatively compared TESC abundance estimates to those of the same 12 species in mixed conifer/deciduous forests of Mount Rainier National Park (MRNP). These data were collected with the same point count protocol during the breeding season of 2003-2004 (Wilkerson et al. 2005). The extensive breeding bird counts which occur in MRNP each year occur in all representative habitats, at all elevations throughout the park. Many habitat types overlapped those found in TESC forests, however mixed conifer/deciduous habitat provided the best overall representation of elevation and topography of sites within MRNP. Abundance estimates were quite similar between the two locations with TESC forests supporting slightly higher densities of all species except Pacific-slope Flycatcher (*Empidonax difficilis)* and Chestnut-backed Chickadee (*Poecile rufescens)* (Figure 5). MRNP had dramatically fewer points with detections and fewer non-flyover detections overall for each species than those at TESC which influenced statistical confidence in density estimates within the mixed conifer/deciduous habitat (Table 1). Overall abundance in mixed conifer/deciduous forests at MRNP (all species pooled) was estimated at 9.19 birds/ha (n=25). Overall TESC bird abundance estimates (all species pooled) for 2008 were 11.86 birds/ha (n=47).

1.32 Habitat densities and community composition

Each 10-meter radius EEON plot represents a random sample of the surrounding forest type since all plot locations were established randomly (see methods). In general, the plot itself is representative of the forest habitat around the plot in which birds were detected. Although our forests represent the broad habitat of Douglas-fir and mixed conifer/hardwood, microhabitats exist in each plot, influencing bird abundances and even detection probabilities (Ralph et al. 1995). Densities range from 10.64 (ind./ha) in mixed hardwood plots to 13.37 (ind./ha) in pure alder plots (Figure 6). Density estimates for hardwood dominated habitats are 12.15 (ind./ha) and 11.55 (ind./ha) for conifer dominated habitats.

Measurements of diversity including species richness, species evenness and Shannon's and Simpson's indices revealed substantial differences among plots but little pattern relating to forest type (Appendix D). Mean species richness was 16.5 species per plot. In general, plots with the highest species richness were either riparian, seasonally wet, or had dominant or pure deciduous overstories. Appendix D provides an overview of community composition among plots and areas of the TESC forest reserve. There appears to be no substantial difference among the south, west, north and east portions of the reserve. Chapter two explores patterns in bird-habitat relationships in closer detail.

1.33 Priority species

Four of the twelve species with density estimates are listed under the PIF North American Landbird Conservation Plan as Tier IIA (see Appendix D) with high regional concern within the Southern Pacific Rainforest Bird Conservation Region (Rosenberg 2004). Based upon BBS data Pacific-slope Flycatcher (*Empidonax difficilis)*, Chestnut-backed Chickadee (*Poecile rufescens)*, Black-throated Gray Warbler *(Dendroica* *nigrescens)* and Purple Finch (*Carpodacus purpureus)* are experiencing declines in the core of their ranges and require conservation action to reverse or stabilize trends (Altman 1999, Rich et al. 2004). These are species with a combination of high area importance and declining (or unknown) population trends (Appendix D).

Aside from these four species that will require diligent monitoring and conservation action in the near future, there are 13 other PIF priority species that I detected of during the 2008 breeding bird survey (Appendix D). These species will likely have reliable density estimates in 2009 and we can begin to estimate our own localized trends within the next five years. Priority species with known population objectives and with reliable abundance estimates at TESC will make for important focal species work on campus (Appendix D). This information will be useful for planning conservation actions. Species in need of additional information on habitat use, reproduction or behavior to order to achieve conservation goals are described in greater detail under research project recommendations in chapter three.

1.34 Nesting species

Although detection of a singing bird is a common indirect method for confirming a breeding species, obtaining any direct breeding evidence is advisable. Many songbird species sing on migration grounds or are detected by calls or movement. While conducting breeding bird surveys, or while moving between survey stations, an observer is likely to witness breeding activity in a variety of forms. I kept a detailed log of all confirmed breeders where breeding behavior other than or in addition to singing was observed. Occasionally nests were located and nest cards following Cornell Lab of Ornithology protocols were created (Cornell Lab of Ornithology 2006). More often behavior indicating a bird with a nest was observed such as an adult carrying food or nesting material, or an adult feeding fledglings or juvenile birds. Locating nests in this fashion is not a quantitative process without a systematic approach, but qualitative and behavioral observation as well as detailed note keeping can aid in the development of nest searching objectives and activities in the future. I confirmed 28 breeding species, nine of which are cavity nesting species requiring snags or decaying portions of live trees for nesting (Table 3).

1.4 Discussion

Our forest reserve hosts a variety of migrant bird species which rely on forested habitats for successful breeding. The forest ecosystem hosts significant populations of Neotropical migrants, including, Pacific-slope Flycatcher (*Empidonax difficilis*), Swainson's Thrush (*Catharus ustulatus*), Black-throated Gray Warbler (*Dendroica nigrescens*), Wilson's Warbler (*Wilsonia pusilla*) and Western Tanager (*Piranga ludoviciana*). Several of these species are experiencing regional or continental declines (Rich et al. 2004, Rosenberg 2004) and should be monitored for any population changes through breeding surveys, nest searching and mist netting efforts.

The densities of 7 species of birds I estimated were slightly higher than those recorded for the same species in other unmanaged forests of Washington by the same sampling methods (Siegel et al. 2004, Wilkerson et al. 2005) but it will take several more years to confirm this trend because confidence intervals for both locations overlapped. If this is in fact the case, it is unknown if factors or a combination of factors, such as proximity to salt water, elevation or a suburban interface are influencing these densities. First year, baseline data on bird populations always present limitations for inference. Less than 25 % of species detected during the 2008 survey generated reliable density estimates.

Despite this small number of species specific density estimates, generation of species area curves revealed an adequate sample size for the study area (Figure 6). Buskirk and McDonald (1995) found multiple counts per point over the course of one breeding season to yield improved coverage in forested habitats, and probably influenced the results in this study. If time permits, 3 visits to each point during the breeding season is ideal (Buskirk and McDonald 1995, Ralph et al. 1995).

Detections vary greatly among species, depending on degree of vocalization and life history strategy and time of breeding (Buskirk and McDonald 1995), as well as among observers (Buckland et al. 2001). Species with large territory sizes such as (Band-tailed Pigeon (*Patagioenas fasciata*) and Pileated Woodpecker (*Dryocopus pileatus)* are difficult to estimate abundances for because they are not likely to be recorded frequently. These species will either require several seasons of point counts to generate reliable density estimates, or a larger survey area encompassing multiple home ranges. Additionally, a greater amount of survey time is needed to confirm the presence or absence of some species (Ralph et al. 1993, Buskirk and McDonald 1995). In the future, with the addition of banding and nest searching monitoring tools to the monitoring program, the number of species EAMP can include in analyses of population data will increase.

The use of VCP point counts require more training and attention to standardization than other methods of bird surveys such as fixed radius point counts, area searches, or spot-mapping (Reynolds et al. 1980, Ralph et al. 1993). Abilities to accurately estimate distances can vary greatly among observers and concern regarding observer bias and data accuracy has been voiced in the literature (Hutto and Young 2002;2003). Over 90 percent of detections during the 2008 survey at TESC were aural, indicating a need for training materials and bird song identification proficiency to become a major component of the breeding bird survey. With skilled observers training newcomers from year to year, the continued sustainability of EAMP and the replication and comparability of results to other monitoring programs and regions should remain the top priority. During the planning stages, it is likely experimental and pilot work will continue to shape the direction and protocols of the monitoring program.

Although much troubleshooting and pilot work will need to continue over the next few years, the completion of the first season of EAMP and the collection of initial count data is a major step forward in the initial phases of the program. Long-term population monitoring is essential to detect biologically significant changes to a population (Hutto and Young 2002). Reliable population trends and density estimates for a number of species will allow faculty and students involved in EAMP to develop meaningful and testable hypotheses for future research. Scientific information about avian populations and habitats on campus should be effectively disseminated to not only managers and planners of the college, but applied to regional policy and management decisions influencing temperate rainforest habitats.

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Tables

Table 1. 2008 abundance estimates for 12 common breeding species in the Evergreen State College forest reserve, Olympia, WA. Species density comparisons to conifer/decidious forest in Mount Rainier National Park, Washington are shown.

The Evergreen State College										**Mount Rainier National Park**					
Species[1]	points with detections	detections	Density (ind./ha)	CV[2]	UCL[3]	LCL[3]	Total abundance	UCL	LCL	points with detections	detections	Density (ind./ha)	CV[2]	UCL[3]	LCL[3]
PSFL	44	167	0.98	9.02	0.82	1.16	409.64	342.76	484.88	15	22	1.34	22.20	0.86	2.10
CBCH	31	80	0.48	14.19	0.36	0.63	200.64	150.48	263.34	16	31	3.60	25.90	2.17	5.98
RBNU	36	66	0.38	13.97	0.29	0.50	158.84	121.22	209.00	5	6	0.08	75.50	0.02	0.31
WIWR	47	229	1.33	7.95	1.14	1.55	555.94	476.52	647.90	14	20	0.58	22.70	0.37	0.92
SWTH	43	145	0.86	10.12	0.70	1.05	359.48	292.60	438.90	9	13	0.20	38.90	0.10	0.43
AMRO	46	231	1.32	8.30	1.12	1.56	551.76	468.16	652.08	4	5	0.13	53.30	0.05	0.35
BTYW	32	69	0.40	14.03	0.30	0.53	167.20	125.40	221.54	2	2	0.09	69.90	0.02	0.32
WIWA	40	119	0.69	10.39	0.56	0.85	288.42	234.08	355.30	2	2	0.10	70.10	0.03	0.39
WETA	32	69	0.40	14.18	0.30	0.53	167.20	125.40	221.54						
SPTO	39	125	0.73	10.25	0.60	0.89	305.14	250.80	372.02						
SOSP	47	180	1.09	9.04	0.91	1.30	455.62	380.38	543.40	6	8	0.39	45.50	0.16	0.95
PUFI	37	85	0.51	12.16	0.40	0.65	213.18	167.20	271.70						

1 See appendix A for latin names
2 CV = Percent coefficent of variation
3 Upper and lower confidence intervals of 95%

Table 2. Breeding species confirmed by behavioral and direct nest observation. Astricks indicate possible focal species to be included in color banding and nest searching activities based on their abundance and life history strategies.

Latin Name	Common Name
Haliaeetus leucocephalus	Bald Eagle
Accipiter cooperii	Cooper's Hawk
Patagioenas fasciata	Band-tailed Pigeon
Selasphorus rufus	Rufous Hummingbird
Sphyrapicus ruber	Red-breasted Sapsucker
Picoides pubescens	Downy Woodpecker
Picoides villosus	Hairy Woodpecker
Dryocopus pileatus	Pileated Woodpecker
Empidonax difficilis	Pacific-slope Flycatcher
Vireo gilvus	Warbling Vireo
Cyanocitta stelleri	Steller's Jay
Corvus corax	Common Raven
Poecile atricapillus	Black-capped Chickadee
Poecile rufescens	Chestnut-backed Chickadee
Sitta canadensis	Red-breasted Nuthatch
Certhia americana	Brown Creeper
Troglodytes troglodytes	*Winter Wren
Catharus ustulatus	*Swainson's Thrush
Turdus migratorius	*American Robin
Dendroica nigrescens	Black-throated Gray Warbler
Wilsonia pusilla	*Wilson's Warbler
Piranga ludoviciana	Western Tanager
Pipilo maculatus	*Spotted Towhee
Melospiza melodia	*Song Sparrow
Junco hyemalis	*Dark-eyed Junco
Carpodacus purpureus	Purple Finch
Carduelis pinus	Pine Siskin

Figures

Figure 1. Aerial view of TESC campus outlined in yellow. Residential development has reduced forest cover surrounding the campus, as exemplified in the area northeast of the forest reserve.

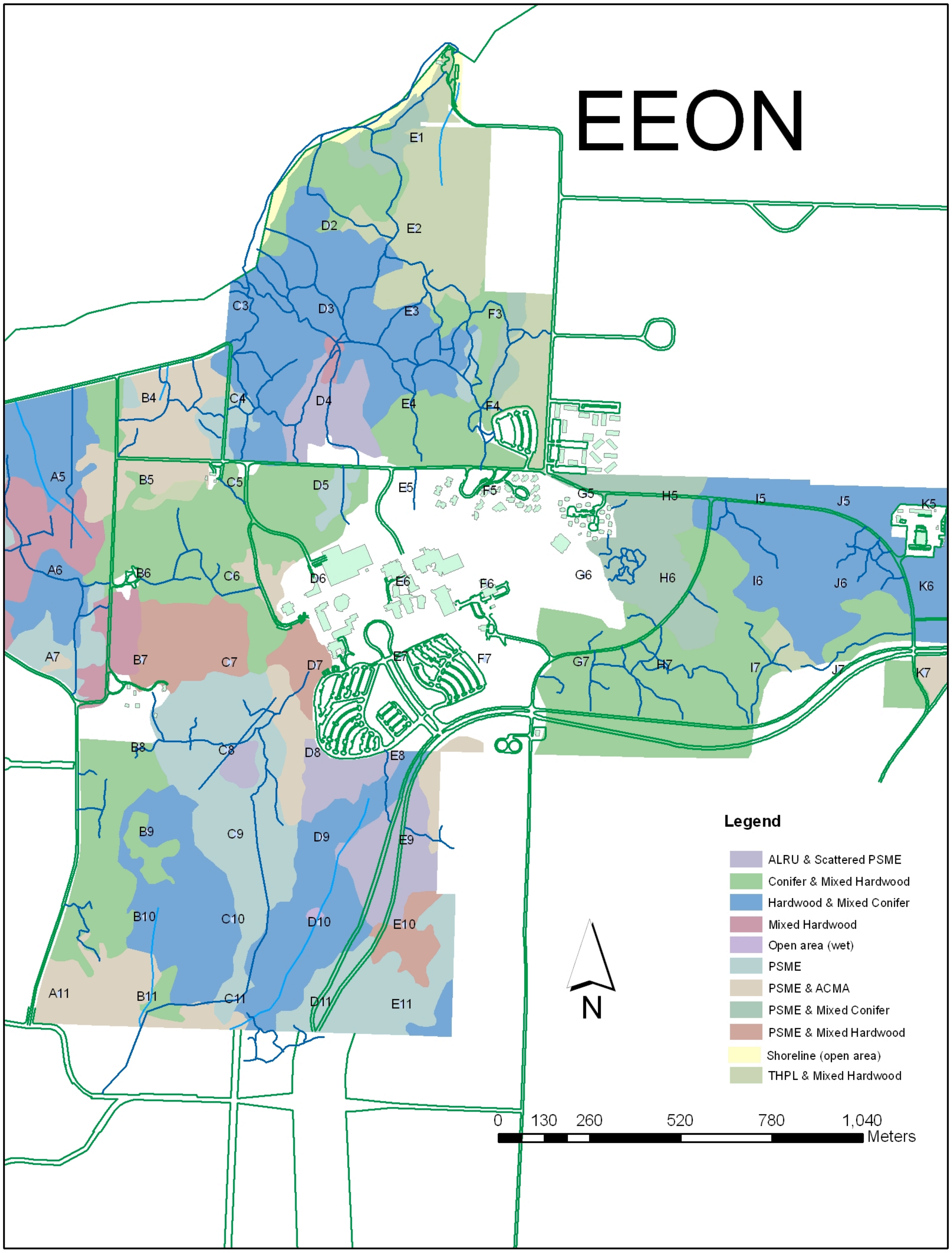

Figure 2. Map of EEON permanent forest plots and forest types

Figure 3a.1939 Orthophoto of the western half of future TESC property showing extensive land clearing (scanned and prepared by C. Adair)

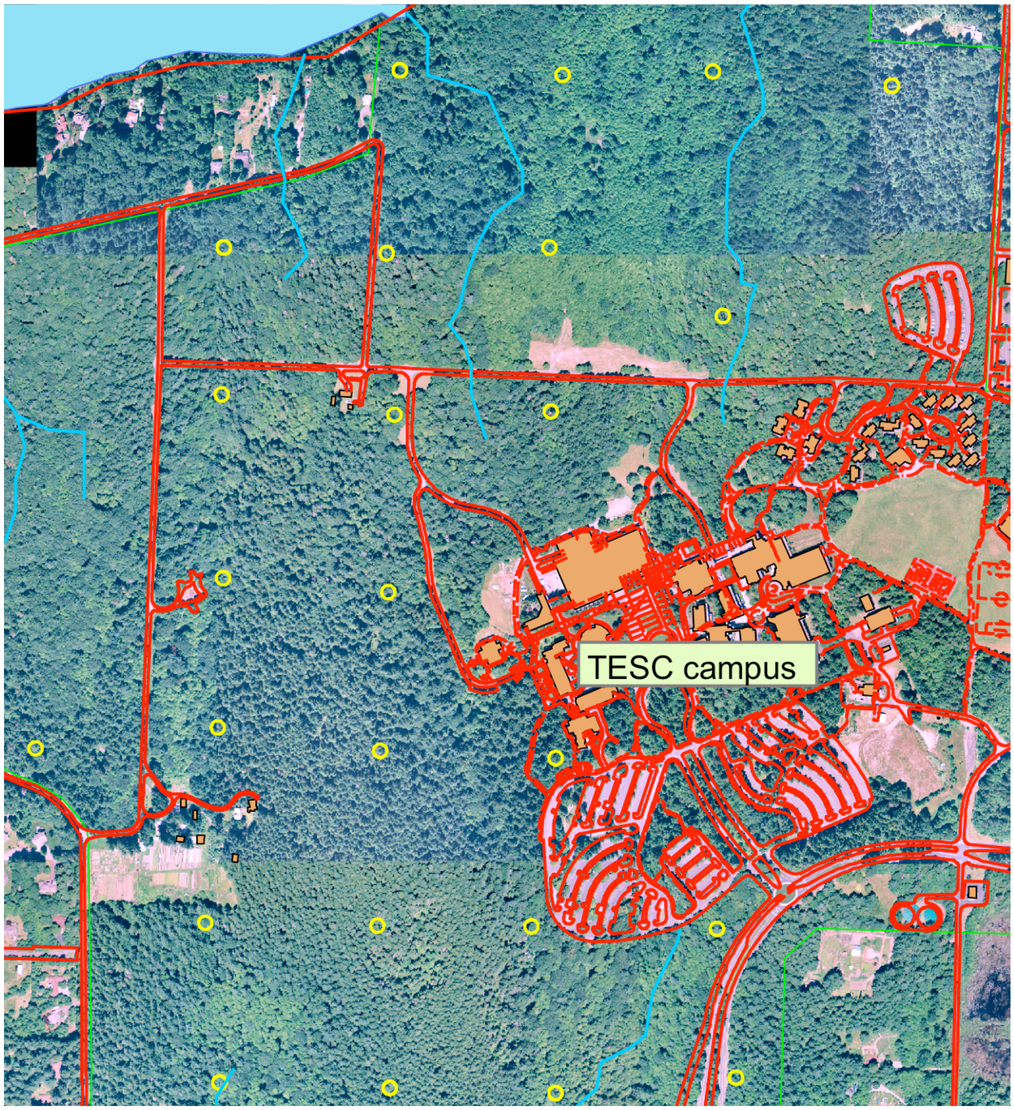

Figure 3b. Western half of TESC property as it looks today with large scale forest regeneration and an average forest age of 80 years.

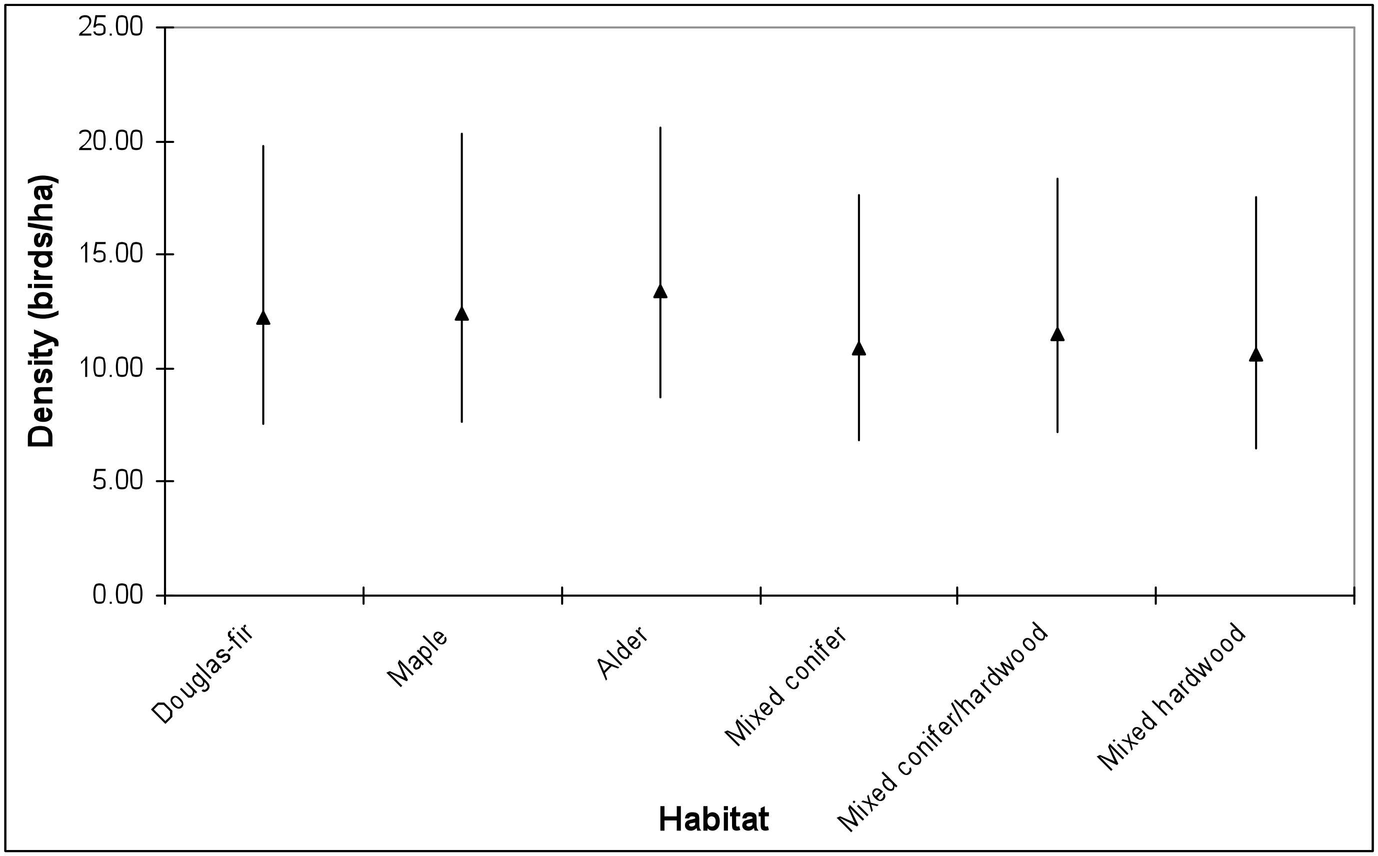

Figure 4. Density estimates for all species pooled for each habitat type (confidence intervals of 95%).
The average bird density in hardwood habitats was 12.15 birds/ha, while the average in conifer forests was 11.55 birds/ha.

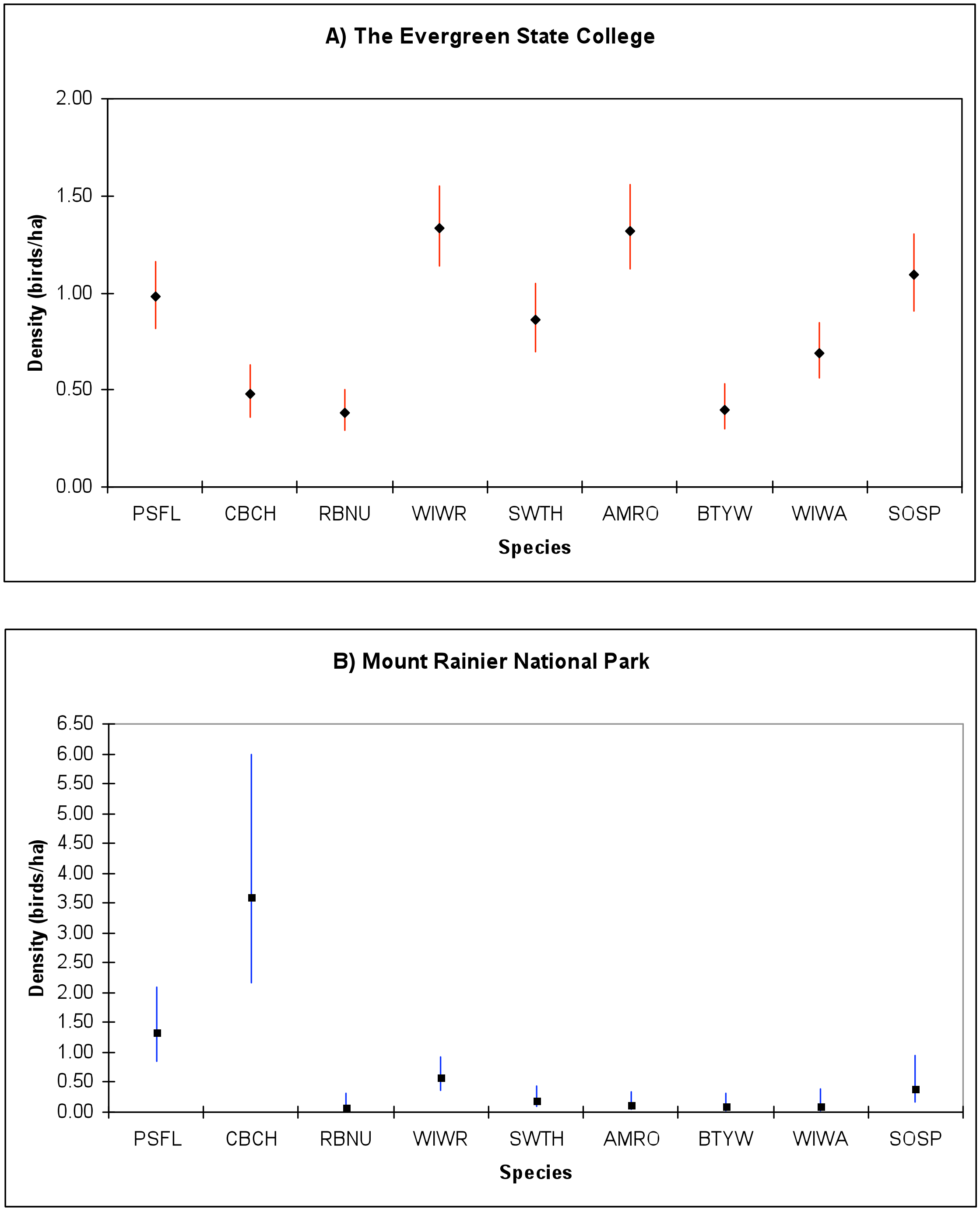

Figure 5a. Density estimates (with 95% confidence intervals) for 9 bird species detected in mixed conifer/deciduous forests of The Evergreen State College, Washington.
Figure 5b. Density estimates (with 95% confidence intervals) for 9 bird species detected in mixed conifer/deciduous forests of Mount Rainier National Park, Washington. Bird species acronyms are defined in Appendix A.

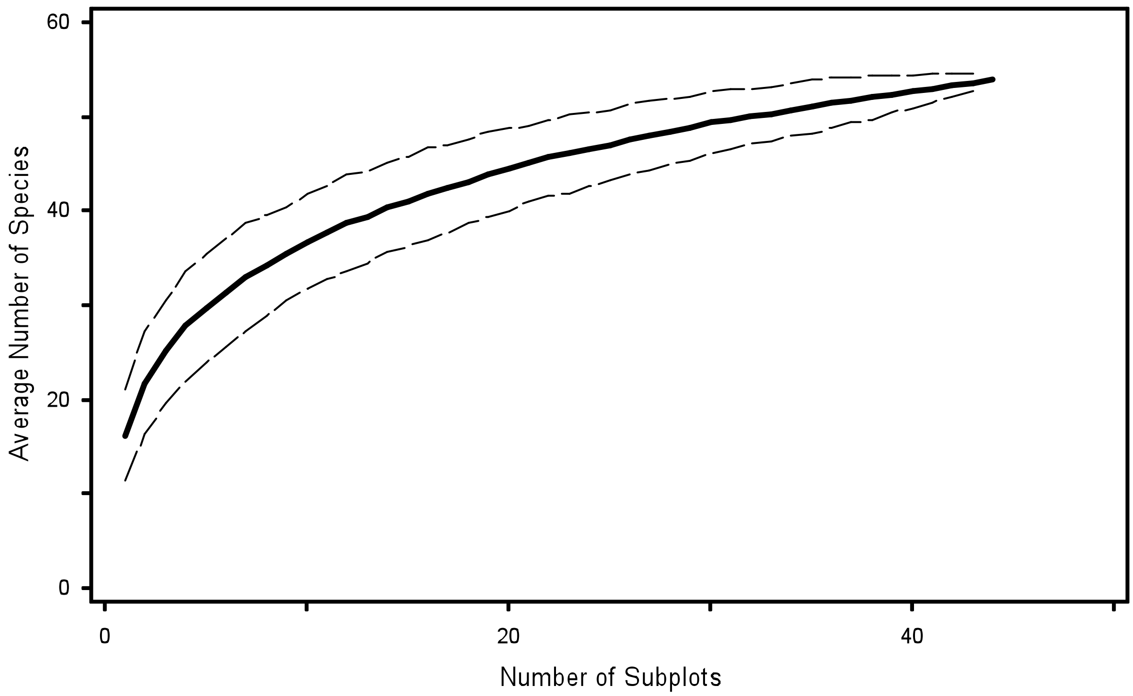

Figure 6. Species area curve for forest birds sampled in EEON forest plots during the 2008 breeding bird survey. Dashed lines indicate 95% confidence bands. The number of species detected (54) begins to level off around 30 subplots.

Chapter Two

Influence of Forest Structure on Birds in a Lowland Puget Sound Rainforest

Abstract

Birds are indicators of ecosystem health and provide a number of ecosystem services such as pollinating plants, dispersing seeds and controlling insect and rodent populations. In this study I explore the relationship between a bird community in a lowland, second-growth temperate rainforest and the forest structure and vegetation attributes measured in 44 permanent forest plots. I hypothesized that 1) the bird community would differ significantly among habitat types and 2) several structural attributes of the forest would be important predictors of bird abundance and diversity. I predicted positive avian community responses to 1) abundance of deciduous trees 2) increases in the decay stage and class diversity of course woody debris (snags and downed woody debris (DWD) and 3) increases in understory plant species richness, cover and sapling biomass. Community ordination revealed significant differences in avian community structure among habitat types and comparison of regression models suggested deciduous overstory was the best predictor of total bird abundance. Sapling biomass had a positive relationship to avian diversity, but not abundance. Indicator species analysis revealed species specific examples in relation to habitat type. While these findings are supported with data from only one breeding season, long-term data collection will help to test and evaluate the best predictors of bird abundance and diversity in Pacific Northwest lowland temperate rainforests.

2.1 Introduction

Structural attributes of forest stands are recognized as important to understanding and managing forest ecosystems. Structure is the attribute most often manipulated in management, is a readily measured surrogate for functions that are otherwise difficult to measure directly, and has direct values for products or ecosystem services (Franklin et al. 2002). In the Pacific Northwest, there is a widely recognized need to both retain existing coniferous old-growth forest and allow young and mature forests to develop structural attributes of old-growth (Ruggerio et al. 1991, Altman 1999). Due to their structural complexity, the western hemlock forests of Oregon and Washington that constitute the majority of coniferous forests, are a high priority for regional avian conservation plans (Altman 1999, Rich et al. 2004, Rosenberg 2004). The coniferous forests of TESC have been unmanaged for over 40 years and are transitioning from young to mature with stand ages around 80 years old (Spies and Franklin 1991). The younger forests preserved by TESC will provide recruitment into old-growth status over the next several decades, contributing to wildlife habitat and regional bird conservation efforts.

Mature coniferous forests support many avian species who rely on their multi-layered structural complexity for successful breeding (Rosenberg 2004). Dozens of studies have examined the response of breeding birds to forest structure at both the stand and landscape levels, often with conflicting results (MacArthur and MacArthur 1961, Thomas et al. 1979, Manuwal 1991, Ralph et al. 1991, McGarigal and McComb 1995, Willson and Comet 1996, Sallabanks et al. 2006). Despite these mixed results, the importance of some habitat characteristics for breeding birds in coniferous forests has been documented through multiple scientific studies. They include decay stage and size of snags (Thomas et al. 1979, Cline et al. 1980, Ganey and Vojta 2004), canopy heterogeneity and diversity in foliage height (MacArthur and MacArthur 1961, Beedy 1982), forest floor complexity (Maser et al. 1979, Hansen et al. 1995, Bull et al. 1997) including understory vegetation (Hagar et al. 2007), and tree species richness, density and canopy cover (James and Wamer 1982, Verner and Larson 1989). All of these forest attributes, however, may exhibit high variability within maturing second growth forests (Rosenberg 2004).

The presence of large live trees have important implications for avian conservation efforts in coniferous forests (Rich et al. 2004). Large trees provide nesting and foraging resources for many landbird species. For example, the presence of deeply fissured bark increases the surface area for bark foraging birds such as the Brown Creeper (*Certhia americana*) (Weikel and Hayes 1999). Layering of vegetation within the mid-story of mature coniferous forests provide vertical gradients which enhance complexity and density of the overall canopy cover (MacArthur and MacArthur 1961), likely influencing avian diversity, abundance and community composition (Hansen et al. 1995, Hagar et al. 1996, Willson and Comet 1996). Multiple layering tends to reduce the amount of understory vegetation due to light limitations, but allows for an extensive organic debris layer to form over the forest floor, especially with the presence of deciduous tree species (Ralph et al. 1991). The presence of deciduous trees contributes to litter layer depth in coniferous dominated Pacific Northwest forests (Ruggerio et al. 1991). Forest floor associated species then utilize this litter layer (Davis 1957, Bull et al. 1997). Many forest birds forage on and nest in deciduous trees in coniferous forests (Beedy 1982, James and Wamer 1982, Gumtow-Farrior 1991, Ruggerio et al. 1991, Hansen et al. 1995, Donovan et al. 2002, Norris and Pain 2002, Hagar et al. 2007). An increase in avian diversity in hardwood patches may be driven by mechanisms such as richness in fruits and foliage-dwelling insects and higher densities of cavities per tree in some hardwood species (Gumtow-Farrior 1991). In Puget Sound lowland forests, deciduous trees can contribute significantly to canopy cover during the late spring and summer months (Table 3). Dense stands of conifer trees impede development of an understory, which reduces overall biodiversity and may limit some species (Altman and Hagar 2007) while providing habitat for others needing access to an open forest floor (Hansen et al. 1995).

Hardwood verses conifer dominance may play an especially important role in avian responses to forest structure. In Pacific Northwest second-growth forests hardwoods often dominate young stands, and there is evidence of further recruitment of hardwood from sapling counts (Appendix D). Species such as Pacific-slope Flycatcher (*Empidonax difficilis*), Black-throated Gray Warbler (*Dendroica nigrescens*) and Wilson's Warbler (*Wilsonia pusilla*) have been found to exhibit associations with hardwood mosaics within coniferous landscapes (Ruggerio et al. 1991, McGarigal and McComb 1995, Hagar et al. 1996).

Canopy gaps may also play a role in shaping forest bird communities. In unmanaged forests, openings in the canopy due to mortality from root rot and other natural events provide further opportunities for development of a deciduous understory. Canopy gaps in themselves may have important implications for forest bird distribution, essentially creating edge effects (Harris 1988). Birds near edges suffer from increased nest predation and cowbird parasitism (Marzluff and Sallabanks 1998, Manuwal and

Manuwal 2002), however avian diversity may increase in canopy gaps, as proximity to preferred habitat increases and as species that favor more open habitat move in (Sallabanks et al. 2000). Naturally occurring canopy gaps within the forest reserve as well as the proximity of agricultural land and roads may have an important influence on avian community composition.

Many species of birds in temperate forests use or are dependent upon dead standing trees (snags) for breeding or foraging (Cline et al. 1980, Spies et al. 1988, Bull et al. 1997). In the past few decades the importance of snags to wildlife, especially primary and secondary cavity nesters, has gained increasing attention (Thomas et al. 1979). Cavity nesters and snag foragers play a critical role in forest ecosystems by eating insects and controlling pest outbreaks (Bull et al. 1997). The quality and size of snags are considered to be a primary factor in maintaining healthy populations of cavity-dependent species (Cline et al. 1980, Hallet et al. 2001, Ganey and Vojta 2004, Spiering and Knight 2005, Smith et al. 2008). Snag size and density in second-growth forests vary greatly due to past forestry practices. In unmanaged forests, even of a relatively young age, there is a regular supply of dying and dead trees due to natural processes of decay. The recruitment of large snag size (>100cm) however, is dependent on the death and decay of large trees (Spies et al. 1988). Conservation efforts for sang dependent and associated species are underway, including snag management practices which allow recruitment to occur through the retention of large live trees and the creation of artificial snags (Hallet et al. 2001).

The majority of snag research has focused on understanding and managing for snag density, but several recent studies indicate that snag quality (decay stage, diameter and height) may be a better predictor of snag-dependent bird abundance (Bull et al. 1997, Spiering and Knight 2005, Smith et al. 2008). One possible indicator of snag quality may be the representation of many different stages of decay, referred to hereafter as snag stage diversity. Birds that use snags do so for different reasons and select for different direct or indirect food and nesting resources that snags of different decay stages provide. For example, following the concept of ecological niches (MacArthur 1958, Wiens 1992), one might expect to find an increase in snag dependent species if more decay stages are available.

Other course woody debris (CWD) such as logs, root wads and branches also play an important role for Pacific Northwest wildlife, including forest birds (Spies et al. 1988, Bull et al. 1997, Rosenberg 2004). Species that forage and nest on or near the ground and within the understory are associated with complex vegetative structure and habitat attributes which provide food, cover, perching locations, and nesting sites (Maser et al. 1979). In managed forests, forest floor components such as downed logs, stumps, and root wads are often reduced thus impacting associated forest birds (Altman 1999, Rosenberg 2004). Ground foraging species such as thrushes (*Turdidae*) (Mack and Yong 2000) and sparrows (*Emberizidae*) rely on decaying organic debris generated from CWD because of the abundance of arthropods found there (Davis 1957). Manuwal (1991) predicted forest fragmentation and simplification of forest structures such as DWD through management practices, to result in the decline of forest floor associated species.

Finally, plant species composition certainly can have a strong effect on avian communities. Multilayered versus single-layered forest canopies clearly can affect avian diversity and abundance (see above). However, understory diversity may also affect avian communities. Understory plants in Pacific Northwest coniferous forests contribute to the majority of the forest's vegetative diversity (Spies and Franklin 1991). A dense understory in conifer dominated forests provide an abundant food resource of flowers, seeds, fruits and insects for birds (Willson and Comet 1996). Some studies examining the role of understory vegetation in avian responses to forest structure show that higher plant species richness provides for a higher number of avian species because of unique foraging and nesting needs (Altman and Hagar 2007). Other work in Pacific Northwest coniferous forests found strong nesting associations of some species to particular plants (Leonard 1998, Leu 2000). Hagar et al (2007) found species specific foraging associations to specific plants that hosted distinct arthropod communities. The understory component of forest structure as been largely neglected in forest management practices and may be a significant driver for some species in the forest bird community.

The purpose of this study is to examine baseline data of a Puget Sound temperate rainforest avian community in relation to forest structure by asking the question: What are the best predictors of avian abundance and diversity? To achieve this objective, I analyzed the response of forest birds to four primary measures of forest structure: the abundance, size and quality (decay stages) of snags, the number and quality (decay classes) of downed-woody debris (DWD), overstory species composition (forest type) and canopy cover, understory vegetation cover and species richness, and sapling richness and biomass (Table 1). First, I tested whether forest type (Douglas-fir, mixed conifer, mixed conifer/deciduous or deciduous) and the degree of a deciduous overstory influenced the avian community and whether the distance to the nearest canopy gap (>.20 ha) was positively related to avian abundance or diversity. I predicted hardwood dominated stands to have the highest diversity of birds and increases in a deciduous overstory to positively influence avian abundance and diversity. I predicted avian abundance and diversity to also increase with decreasing canopy gap distance. Second, I examined snag characteristic data with 13 species of snag-dependent birds detected during point counts during the 2008 breeding season (Appendix D). I predicted snag quality and snag-dependent bird abundance and diversity to be positively related. Particularly, snag decay stage diversity should be a stronger driver of this bird community than snag density alone. Congruently, the same attributes for snags should also apply to DWD. Specifically, I predicted DWD abundance, decay class and decay class diversity to be positively related to forest floor associated birds (Appendix D). Third, I tested whether understory cover, species richness, and sapling richness and biomass influenced avian species associated with the understory. I predicted understory cover and understory plant species richness to be positively related to avian abundance and diversity. Because saplings contribute to a large amount of overall understory biomass and provide additional foraging area for insectivores (see above), I also predicted sapling biomass to increase avian abundance and diversity. Finally, I discuss the results in relation to the findings of other bird-habitat studies in similar ecosystems.

2.2 Methods

2.21 Study site

My study took place on The Evergreen State College (TESC) forest reserve located three miles northwest of Olympia, Washington (approx. 47°04’N, 122°58’W) in a network of permanent plots hereafter referred to as the Evergreen Ecological Observation Network (EEON). The EEON permanent plot network consists of 44 10-meter radius permanent plots created in 2006 in a 250-meter grid across the reserve (http://academic.evergreen.edu/projects/EEON - accessed 3-31-09). Acquired in 1968 and representing the largest land area of any college in Washington State, the forest reserve comprises over 80% of the entire campus and approximately 314 hectares (Zimmer Gunsul Frasca Architects 2008) . The land was previously owned by the Washington Department of Natural Resources (DNR) and was last clear cut between 1937 and 1939 (Figure 2a, 2b). The reserve also includes 3,300 feet of waterfront on Eld Inlet of the Puget Sound adding to its ecological diversity. The forest is primarily Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) dominated with substantial stands of hardwood (*Alnus rubra* Bong. and *Acer macrophyllum* Pursh), western red cedar (*Thuja plicata* ex D. Don) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) mosaics. Hardwoods make up an average of 38% of all trees within permanent plots at this study site (Table 2; data from EEON). Along coastal plots, mature grand fir (*Abies grandis* (Douglas ex D. Don) Lindl.) are present, and throughout the reserve pacific madrone (*Arbulus menziesii* Pursh), Scouler's willow (*Salix scouleriana* Barratt ex Hook.) and black cottonwood (*Populus balsamifera* L. ssp. *Trichocarpa* (Torr. & A. Gray ex Hook.) Brayshaw) are also present. Much of the understory vegetation with adequate light is dominated by dense thickets of sword fern (*Polystichum munitum* (Kaulf.) C. Presl), salal (*Gaultheria shallon* Pursh) and Oregon grape (*Mahonia nervosa* (Pursh) Nutt.). The topography of campus is generally flat with the highest elevation at 74 meters above sea level. The landscape is characterized by gentle slopes bisected by five steep-sloped, short (mostly ephemeral) streams with headwaters within, or just outside of the reserve, and steep bluffs along the waterfront of Eld Inlet. My work took advantage of a new network of 44 10-meter radius permanent plots created in 2006 in a 250 meter grid across the reserve (http://academic.evergreen.edu/projects/EEON).

2.22 Avian data collection

I conducted five minute variable circular plot (VCP) point counts from 23 April to 22 June 2008. I recorded all birds seen and heard, excluding birds that flew overhead and did not appear to be utilizing the habitat, in 47 established forest plots. I visited each plot once in the early season and once in the late season to equally sample early nesting resident species and late nesting migratory species. I recorded the horizontal distance to the nearest meter for each bird detected with the aide of laser rangefinders and flagging. Each survey was separated into 3 and 2 minute periods, beginning within 30 minutes of local sunrise and concluding 3 hours after sunrise (Ralph et al. 1995). Separating observations into the first three minutes and last two minutes improves comparability with Breeding Bird Survey (BBS) routes which utilize three minute counts. In this study, data was analyzed from the full five minute count. All other avian species not associated with the habitat including flyovers, were listed separately. Environmental data including cloud cover, temperature, wind, precipitation and noise level (scale of 0-3) were also recorded. Surveys were suspended due to high winds (>10mph) or precipitation which penetrated the forest canopy. Environmental variables recorded for each survey can be tracked over time to reveal potential causes influencing avian populations. The level of road or construction noise can influence detection rates because detections in dense forested habitats are generally greater than 90% aural (Ralph et al. 1995).

2.23 Forest structure and vegetation data collection

Forest structure and vegetation variables were collected by students and faculty of the

Evergreen State College over the course of two years, between the summer of 2006 and the summer of 2008 (Kirsch et al. *in prep,* Fischer et al. *unpublished*). Intensive structural data was first collected for 21 plots located in the south end of the forest reserve. Forest structure variables and methods were determined by the EEON network during its inception in 2006. The forest structure data used in this study and their methods are described below and are stored in an online database (Evergreen Ecological Observation Network 2008). A complete list of all plant codes, common and scientific names are provided in Appendix B. I conducted bird surveys in 47 plots of the network, but used habitat and vegetation data for 44 plots (plots K7, K6 and J5 are omitted from habitat analysis because forest structure data was not available).

2.231 Habitat typing

Forest types were ascertained through a student research project which utilized aerial photography and GIS technology (Greenberg and Hartley *unpublished*). Greenberg and Hartley's (*unpublished)* original work consisted of nine distinct forest types (Figure 3). I simplified their forest typing classification system to help elucidate any possible differences in habitat selection for avian species detected in these habitats. I did this by ground-truthing each plot and its surrounding area, comparing it visually in the field to the 1998 data, and then matching the plot with either a) Douglas-fir, b) mixed conifer, c) mixed conifer/hardwood, or d) hardwood, based on visual estimates of percent cover.

2.232 Trees

Each live tree within the plot was measured for tree species, diameter at breast height (DBH) (cm), height (m), and height to live crown (m). Tree and live crown height were determined using a Sunto® clinometer (Vantaa, Finland) and laser rangefinder

(U.S. Department of Agriculture Forest Service 2005). I took all canopy cover measurements using a spherical densitometer after the completion of each bird survey. I used the average of the two surveys to determine the canopy cover for each plot during the survey period (April-June). Tree biomass was determined using allometric biomass estimation equations from the database software package BIOPAK (Means et al. 1994) similar to (Kirsch et al. *in prep*) (see http://academic.evergreen.edu/projects/EEON/). I calculated the distance to the nearest canopy gap (>0.20ha) in ArcMap GIS (Environmental Systems Research Institute 1992-2005) using recently obtained Light Detection and Ranging (LiDAR) data. Briefly, a raster calculator was used to develop a map of tree height based on subtraction of high hits and bare earth hits from recently obtained LiDAR data (Watershed Sciences Inc. 2008, Stewart 2009)

2.233 Snags

All snags occurring within the plot were measured for tree species, height (m), DBH (cm) and decay stage. Heights were measured using the same methods as live trees except when a reliable estimate (<3 meters) was possible. Snag decay was evaluated on a scale of 1-9 from the classification system developed by the USDA Forest Service (Thomas et al. 1979). The stages are identified as; dying tree with green remaining (1) decline (2-browning of needles), death (3-loss of needles, but fine branching still evident), loose bark (4 loss of fine branching, cracks in bark), bark lost (5-tew branches remain), broken (6 top of tree lost), decomposed (7 advanced decay, additional breakage of the trunk). Down material (8-most of trunk is on the ground), and stump (9). As many relic old growth stumps remain, stumps were noted as cut if such a determination was possible.

2.234 Downed Woody Debris

Downed woody debris (DWD) are classified from snags when they lean at or below a 45 degree angle. They include dead downed and dead trees, shrub boles, and tree limbs. Each piece of DWD over 10cm DBH (known as course woody debris) was measured for volume using three diameter measurements (one at each end and one in the center) and total DWD length (Harmon and Sexton 1996). Mass of DWD was determined using volume multiplied by estimated decay-stage-specific density form Harmon and Sexton (1996). Decay class was assigned on a scale of 1-5 from the classification system described in Maser et al (1979). In this study, only the numbers of course DWD present in the plot were used in analyses and fine downed woody debris were not measured or counted. DWD biomass was not included in this study.

2.235 Saplings

Sapling counts were completed for each plot during the summer of 2008. Saplings were defined as woody species with a diameter less than 5cm. Saplings were separated into trees and woody shrubs and included as trees one meter or taller and woody shrubs two meters and taller. Trees were defined as those which were representative of the dominant overstory. This allows for saplings that have the greatest chance of survival to maturity to be included in the sapling count so presence and diversity of saplings may be tracked over time. The numbers of each species of sapling was recorded for plot and DBH measurements were taken. Sapling biomass was then calculated using allometric biomass estimation equations from the database software package BIOPAK (Means et al. 1994).

2.236 Understory vegetation transects

We determined understory cover and diversity using point intercept transects in each cardinal direction from the center post to plot edge (Brower et al. 1998). The numbers of hits every 10cm along the 100cm transect were recorded for each species or as bare ground. We identified all vascular plants except grasses to species (Hitchcock and Cronquist 1973). If trees and shrubs were encountered along transects they were counted only if they did not meet the height requirements for saplings. Total percent cover, species richness and diversity indices were calculated for each plot.

2.24 Data Analysis

I generated community indices for all avian species detected, including relative abundance, species richness and diversity (McCune and Mefford 1999, McCune and Grace 2002). For this general community analysis, I used 21 habitat variables for live trees, snags, DWD, saplings and understory vegetation (Table 1). For community analyses I used an ordination technique known as non-metric multidimensional scaling (NMDS) with a Bray-Curtis distance measure to examine the avian community among multiple habitat variables. The equivalent to an ANOVA procedure, differences in the avian community and forest type were tested using a multi-response permutation procedure (MRPP) in PCORD (McCune and Mefford 1999, Gleneden Beach, OR). Analysis of Variance (ANOVA) with post hoc comparisons (Tukey's Honest Significant Difference (HSD)) was used to further test for differences among forest type for avian abundance, species richness and diversity. I used bi-plot vectors in PCORD to distinguish any strong correlations potentially driving the avian community. Pearson's correlation coefficients were used to quantify correlations of the community similarity matrix with habitat variables along axis 1 and 2. I then used post-hoc regression analysis to test if these correlations were significant. Finally, I preformed an indicator species analysis in the same program with graphical depictions of species ordinations in order to distinguish each species stand type indicator.

Using community indices as dependent variables and structural attributes of the forest as predictors, I used simple linear regression in JMP-statistics 7.0 (academic version, SAS Institute Inc. Cary, NC) to examine support for hypotheses regarding habitat relationships. Because so many predictor variables were examined (see Table 1) results should be viewed with caution since spurious results are more likely when higher numbers of predictor variables are examined in multiple linear regressions. I used Akaike's Information Criterion (AIC) values (Burnham and Anderson 2002) output from JMP regression analysis to begin an exploratory analysis of which variables explained the most variation in the avian communities of each habitat type (i.e. overstory, snags, DWD, understory). Because my analysis was not parsimonious in its choice of factors to analyze, these results should be interpreted with caution. For example, AICc (rather than AIC) should have been used in these analyses due to low sample sizes and analysis of multiple models (see Burnham and Anderson 2002). Additionally, I did not include an intercept model for AIC comparisons, and so my analyses assume that models including predictor variables were more important than intercept only models. Because avian abundance did not met assumptions of normality, I log transformed all relative avian abundance data. All regressions and modeling was completed using an alpha of 0.05 (type I error probability).

2.3 Results

2.31 Trees

I tested whether forest type (Douglas-fir, mixed conifer, mixed conifer/deciduous or deciduous) and the degree of a deciduous overstory influenced the avian community. I predicted hardwood dominated stands to have the highest diversity[1] of birds and increases in a deciduous overstory to positively influence avian abundance and diversity. The MRPP procedure with NMS visualization revealed avian community structure to differ significantly among forest types (MRPP A=0.03, P=0.0008; Figure 3). The MRPP A-statistic shows the effect size of forest type on the avian community. Here a 0.03 shows forest type having a moderate effect on avian community structure (McCune and Grace 2002). Bi-plot vectors along two axes suggested the strongest factor structuring the avian community to be the degree of a deciduous overstory (Pearson's r=0.51, r^2=0.26; Table 2; Figure 3). The degree of understory cover was also a strong driver for the avian community (Pearson's r=0.43, r^2=0.19; Table 2; Figure 3) although these two parameters were weakly autocorrelated (Appendix D). Biplot vectors provide a visual representation of community similarity along 2 axes, however when correlations are restricted to one axis there is increased stress in multidimensional space and therefore stronger relationships (r^2=0.31, r^2=0.19 respectively, Table 2).

Analysis of variance analyses on avian abundance also showed a significant difference among forest types (F=4.44, P=0.009, Figure 4). Post hoc tests suggested this difference could be attributed particularly hardwood stands. Avian species richness and diversity did not differ significantly among forest type (F=2.27, P=0.09, F=1.13, P=0.35 respectively) although they were generally higher in hardwood stands (Figure 4).

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[1] Hereafter I refer to Shannon's diversity index McCune, B., and J. B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, OR. as simply "diversity".

Linear regressions revealed a number of significant habitat relationships for avian abundance, species richness and diversity (Table 4). Supporting ordination findings, the only significant variable predicting avian abundance was percent deciduous overstory (R^2=0.31, P<0.001, Tables 2 and 4, respectively). The degree of a deciduous overstory was only weakly related to avian species richness (R^2=0.07, P=0.04). Deciduous overstory was not significantly related to avian diversity (P=0.23). Although I predicted avian abundance and diversity to increase with decreasing canopy gap distance, I found no significant relationship between avian abundance or diversity and canopy gap distance (P=0.39, P=0.10, respectively). Overstory and tree habitat modeling showed deciduous cover to be the single best predictor of avian community structure (AIC=154.95, Table 5).

2.32 Snags

I predicted snag quality and snag-dependent bird abundance and diversity to be positively related. Particularly, snag decay stage diversity should be a stronger driver of this bird community than snag density alone. The density of snags were only weakly related to avian abundance (R^2=0.10, P=0.02), species richness (R^2=0.14, P=0.007) and diversity (R^2=0.07, P=0.04) and snag decay stage diversity were significantly related to avian richness (R^2=0.12, P=0.01) but not diversity (P=0.05) or abundance (P=0.06). Contrary to my predictions, these attributes of snags had negative relationships to these avian community indices (Figure 6). Snag decay diversity was the best snag habitat model to show an influence on avian species richness (AIC=12.37). The best models for other community indices were snag decay stage for avian diversity (AIC=-104.53) and snag size (DBH) for avian abundance (AIC=202.31).

2.33 Downed Woody Debris

Congruently, I predicted the same attributes for snags should also apply to DWD. Specifically, I predicted DWD abundance, decay class and decay class diversity to be positively related to forest floor associated birds. I found no significant relationships between avian community indices and any DWD variable (Table 4). For DWD, the best models were decay diversity for avian abundance (AIC=-186.25) and species richness (AIC=11.58). For avian diversity, AIC used in model selection were too close for an appropriate model to be chosen (Table 5).

2.34 Understory

For understory forest structure variables, the only significant variable related to avian community structure was sapling biomass (Figure 6). Avian diversity was significantly related to sapling biomass (R^2=0.16, P=0.004, Figure 6) but understory cover was not (P=0.05). Avian species richness was related to sapling biomass as well (R^2=0.11, P=0.02, Figure 6). The best models for understory structure and avian diversity used sapling biomass as a predictor variable (AIC=-170.16). The best model for avian abundance was sapling species richness (AIC=-213.60) and the best model for avian species richness was understory species richness (AIC=38.54).

2.35 Indicator Species Analysis

Indicator species analysis revealed Cassin's Vireo (*Vireo cassinii*), Warbling Vireo (*Vireo gilvus)*, Black-capped Chickadee (*Poecile atricapillus)*, Chestnut-backed Chickadee (*Poecile rufescens)*, Swainson's Thrush (*Catharus ustulatus),* and Song Sparrow (*Melospiza melodia)* to be associated with a particularly forest type (Table 3). Graphical representation of each species matrix and correlation values revealed which stand type drove these indicators (Figure 5). Both species of Vireo (r=0.173, r=0.197 respectively), Black-capped Chickadees (r=0.0628) and Song Sparrows (r=0.625) were indicators of hardwood stands. Chestnut-back chickadees were indicators of coniferous dominated stands (r=-0.581). Swainson's Thrushes were only weakly correlated to conifer stand types (r=0.146).

2.4 Discussion

Forest type is an important factor influencing avian community structure at this study site. Specifically, a deciduous tree component appears to positively influence both avian abundance and species richness. Avian diversity was not significantly affected by deciduous tree abundance, probably because species evenness is lower in deciduous stands (Appendix D). These results corroborate with the findings of other bird-habitat studies in conifer dominated forests (James and Wamer 1982, Willson and Comet 1996). Deciduous trees represent a small portion of tree biomass (Kazakova et al. 2007) at this study site, and appear to be a limiting foraging and nesting resource for many avian species. Contrary to other studies, overstory canopy cover and the height of live crowns (all tree species) did not affect the avian community (James and Wamer 1982). The variation in live crowns and overlapping canopies at different heights that were unmeasured in this study may have confounded these results (MacArthur and MacArthur 1961). Supporting findings in other forested ecosystems, distance to canopy gaps did not play a significant role in shaping avian community structure (Sallabanks et al. 2000 and references therein). In all analyses, my findings suggest deciduous cover to influence the avian community, supported by varying levels of significance.

Contrary to my predictions, the diversity of snag decay stages does not appear to provide additional bird habitat for a wider array of species in this study area. I observed fewer species in plots with many different stages of decay. These results could mean snag-dependent birds are selecting for only a few specific decay stages of snags that offer the best nesting and foraging resources. Brown Creepers (*Certhia Americana*) and Red-breasted Nuthatches (*Sitta Canadensis*) utilize snags and dying trees with remaining bark harboring insects and places to cache food (Hendricks 1995, Ghalambor and Martin 1999, Weikel and Hayes 1999) . Primary cavity nesters such as woodpeckers and chickadees may prefer snags with more decay, allowing easier excavation (Ganey and Vojta 2004). Since woodpeckers were detected less often than other birds, additional years of sampling, with additional woodpecker detections, many provide very different snag decay stage diversity results. Despite these initial results being contrary to my predictions, this study is the first I know of to utilize plot level snag data to quantify snag decay stage diversity.

My snag density results are contrary to the findings of several other snag studies (Bull et al. 1997, Spiering and Knight 2005, Smith et al. 2008) and should be viewed with caution. It is possible that each permanent plot where snags were sampled was too small (20m diameter) to adequately represent the surrounding landscape of snags. It is also likely that 2 5-minute counts over the entire breeding season did not allow for an adequate sampling of less common snag-dependent bird species (i.e. woodpeckers). Here, all snags regardless of size were used in analyses, however future analyses might truncate a minimum snag diameter to include in density estimates. Additionally, several seasons of surveys will be necessary to understand how snag availability in this study area influences the abundance, richness and diversity of birds. Further research should quantify avian use of cavities found in order to determine the role of snag decay stage and snag size on cavities.

Contrary to other studies (Ruggiero et al. 1991, Bull et al. 1997), forest floor complexity did not significantly influence the diversity and abundance of the forest floor avian community. My findings do suggest avian diversity to be slightly higher in plots with greater understory cover, although the results were non significant (Table 4). Many species may be selecting for nest sites and places to feed dependent juveniles that offer substantial cover over structures such as logs and stumps where arthropods are abundant and a nest site entrance can be well concealed (Willson 1974). In this sense, cover may be more important during the breeding season than the presence of logs of stumps if they are not adequately concealed, but this is highly dependent on the individual bird species.

In this lowland rainforest study site, saplings were comprised of 16 deciduous species and 7 evergreen species, further contributing to a multi-layered and diverse forest (Appendix D). Sapling biomass was the strongest understory driver of avian species richness and diversity. An increase in biomass increases surface area for foraging and may positively influence the numbers of species able to forage there. Hagar (2007) found higher arthropod prey abundance on deciduous than evergreen trees and shrubs in the understory of Douglas-fir forests in Western Oregon. Given the high degree of a deciduous component in the understory of this study site, a greater number of insectivorous species may be foraging there. The extent and nature of avian use in the understory is worthy of future investigation.

Indicator species results for stand type may be attributed to some species being found in only one forest type and their sample size. For example, both species of Vireo were found only in pure hardwood stands but occurred in low numbers decreasing their correlation coefficient (Figure 5). Swainson's Thrushes were only weakly correlated to Douglas-fir and mixed conifer stand types (r=0.146) but were one of the more common species sampled. Swainson's Thrushes favor more open forest floor environments for foraging on arthropods in leaf and needle litter (Mack and Yong 2000). Douglas-fir and mixed conifer forests impede light reaching the forest floor and inhibit understory growth (Ruggiero et al. 1991).

These indicator species results support the findings of previous studies where Black-capped and Chestnut-backed Chickadees are sympatric and have shown resource partitioning (Sturman 1968). In a lowland rainforest of the Pacific Northwest, Sturman (1968) found Black-cap's to be associated with hardwood/deciduous habitat whereas Chestnut-back's were associated with coniferous habitat. An additional study supported these findings by quantifying 3.5 times as many records of Black-capped Chickadees in deciduous trees as in conifers, and more than five times as many records of Chestnut-backed Chickadees in conifers as in deciduous trees (Smith 1967).

Song Sparrows were a somewhat surprising indicator species given their high densities in nearly every forest type of the reserve (chapter 1). Their documented increases in densities near water and riparian areas (Arcese et al. 2002) may be driving their indicator status in hardwood plots. Song Sparrows may occur in higher densities in hardwood plots because of increased food availability; however this should be tested with further study. Given that my indicator species analysis results are somewhat difficult to interpret, it is possible a larger study area with more distinct stand types is needed to fully understand indicator species analysis results and determine if it is a useful tool for birds in these habitats.

The objective of this study was to examine habitat relationships in an avian community in an unmanaged lowland temperate rainforest using data from the first year of a long-term monitoring effort. As with many multivariate datasets there are many factors I was unable to examine in this study that may have influenced the results. Given this data represents the first of its kind at our study site, I was unable to consider community composition changes from year to year. I did not examine the effects of proximity to water or moisture gradients, which has been found to influence avian communities in other regions (Smith 1977, Anthony et al. 1996), species-specific interactions, or the influence of foliage height diversity (MacArthur and MacArthur 1961, Verner and Larson 1989). No other influences above the stand level were examined. Many other factors possibly influenced avian community composition at this study site and should be addressed in future research.

Avian-habitat regressions presented here explained less than 20% of the variation in avian community indices. It should be seriously considered that other factors were equally significant and their contribution may have dramatically influenced R^2 values, their negative and positive relationships, and ordination outputs. These factors may be environmental, or related to differences in individual species ecology.

Comparisons of AIC values to help select the most appropriate habitat model are useful for understanding what predicts avian distribution and composition. Here I compared AIC values only for each habitat type (i.e. either snag, DWD, tree or understory). It would also be useful to compare across all habitat types where all species detected are pooled. These model comparisons will require a larger sample size over more than one breeding season. Other types of model selection methods (Burnham and Anderson 2002) may be valuable in assessing bird-habitat relationships at this study site. Burnham and Anderson describe the importance of parsimonious selection of each predictor variable prior to analysis. Using AICc in model selection analysis may have provided more clearer habitat models as the sample size was low relative to the number of models in this study. In the future an intercept model for each AIC (or AICc) comparison should be used to address assumptions that predictor variable models are more important than their intercept counterpart (see Burnham and Anderson 2002 for further explication of AIC habitat modeling). Because I did not use AICc or intercept models these initial avian-habitat relationships should be viewed with extreme caution.

One avenue to exploring additional variables and to assist in the collection of vegetation data is the use of Light Detection and Ranging (LiDAR) data. LiDAR provides fine grained 3-D data on the physical structure of any terrestrial environment (Vierling et al. 2008). The complexity of temperate rainforests provide an excellent use for this new technology. Although several studies have discussed the theoretical implications for LiDAR (Davenport et al. 2000, Hyde et al. 2005) to influence our understanding of avian habitat preferences, very few studies have examined wildlife data in relation to LiDAR habitat data. Vierling et al (2008) believe LiDAR has the potential to dramatically reduce if not replace labor intensive and time consuming field measurements. This study site now possesses 2008 LiDAR data for a large area including the forest reserve and surrounding areas. The implementation of this analytical tool could provide new insights into how the avian community responds to forest structure. LiDAR data also can expand analyses to larger landscape scales.

To understand patterns of avian community composition in relation to TESC forest structure it will be imperative for avian data collection to continue and possibly for habitat variables to be amended as patterns emerge. With 1-3 years of additional breeding bird surveys, following the same sampling methodologies, a clearer picture of the best predictors of bird distribution in the forest reserve will emerge. Much of the forest structure data now available can be used for several more years before substantial structural changes occur. An exception would be a natural disturbance dramatically contributing to DWD recruitment and other structural attributes of the forest. These long-term data on forest structure and the avian community will provide the college with new insights into the ecology of its forest reserve and elucidate bird-habitat relationships. Understanding how birds and other organisms respond to different forest attributes will inform future land use planning and management of this unique and ecologically valuable tract of land.

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Tables

Table 1. Variables used in habitat community analyses to identify factors driving avian abundance, richness and diversity in the Evergreen State College forest reserve, Olympia, WA.

Structure type	***Response Variables***	**CODE**	**UNITS**	**DESCRIPTION**
	Avian species abundance	BDIV	H'	Shannon-Weaver Index of diversity
	Avian species richness	BSR	species/plot	bird species richness
	Avian species diversity	BAB	log(no./plot)	relative bird abundance log transformed
	Predictor Variables			
LIVE TREES	Habitat/stand type	STTYPE	categorical	1=Douglas-fir, 2=mixed conifer, 3=mixed conifer/hardwood, 4=hardwood
	Canopy gap distance (m)	CPYGAP	m	Distance to nearest canopy gap
	# of trees	TREES	no./plot	number of trees in plot
	Tree biomass (kg)	TRBIO	kg	total tree biomass in plot
	Average tree height (m)	CRHT	m	average height of live crown
	Average crown height (m)	TRHT	m	average tree height
	Deciduous cover (%)	DECDCOV	%	percent deciduous trees
	Overstory canopy cover (%)	CPYCOV	%	average overstory canopy cover
	Tree species richness	TREERICH	no./plot	number of overstory tree species in plot
SNAGS	# of snags	SNAGS	no./plot	number of standing dead trees
	snag DBH (cm)	SGDBH	cm	average snag diameter at breast height
	snag height (m)	SGHT	m	average height of standing dead trees
	Snag decay diversity	SGDECDIV	categorical	average snag decay stage
	average snag decay stage	SGDECSTG	categorical	number of snag decay stages represented in plot
DWD	# of DWD	DWD	no./plot	number of DWD counted in plot
	DWD decay diversity	DWDDECDIV	categorical	number of DWD decay classes represented in plot
	average DWD decay stage	DWDDECCL	categorical	average DWD decay class
UNDERSTORY	Understory species richness	VEGRICH	no./plot	number of plant species, excluding trees and saplings in each plot
	Understory cover (%)	VEGCOV	%	combined cover of all plant species excluding trees and saplings in each plot.
	Sapling biomass (kg)	SAPRICH	no./plot	number of sapling tree species in plot
	Sapling species richness	SAPBIO	kg	total sapling biomass in plot

Table 2. A) Pearson and Kendall correlations with NMS ordination axes (n=44). Decidious overstory cover and understory vegetation cover show the strongest correlations with the avian community. B) correlation results when the ordination is restricted to one axis, showing increased stress in multidimensional space and therefore stronger relationships. These results were then tested for significance with linear regresion (table 4). Variable codes are defined in table 1.

A

Axis:	1			2		
	r	r²	tau	r	r²	tau
CPYGAP	-0.223	0.050	-0.131	-0.226	0.051	-0.203
TRBIO	-0.150	0.023	-0.101	-0.173	0.030	-0.140
CPYCOV	0.142	0.020	0.050	0.046	0.002	-0.010
DECDCOV*	0.511	**0.261**	0.362	0.350	0.123	0.223
TRHT	-0.233	0.054	-0.171	-0.125	0.016	-0.060
CRHT	-0.274	0.075	-0.130	0.057	0.003	0.068
TREES	-0.014	0.000	0.087	0.155	0.024	0.120
TREERICH	-0.046	0.002	0.010	-0.089	0.008	-0.022
SNAGS	-0.326	0.106	-0.101	0.161	0.026	0.120
SGDBH	-0.025	0.001	-0.072	-0.214	0.046	-0.161
SNGHT	0.101	0.010	0.058	0.199	0.040	0.200
SGDECDIV	-0.126	0.016	-0.014	0.129	0.017	0.101
SGDECSTG	-0.238	0.057	-0.097	-0.373	0.139	-0.287
DWD	-0.235	0.055	-0.119	0.046	0.002	0.048
DWDDECCL	0.128	0.016	0.076	-0.111	0.012	-0.099
DWDDECDIV	-0.119	0.014	-0.121	-0.040	0.002	-0.056
VEGRICH	0.156	0.024	-0.006	0.164	0.027	0.092
VEGCOV	0.319	0.102	0.211	0.430	**0.185**	0.347
SAPRICH	0.040	0.002	0.090	0.128	0.016	0.177
SAPBIO	0.148	0.022	0.112	0.250	0.062	0.222

B

Axis:	1		
	r	r²	tau
CPYGAP	0.282	0.080	0.239
TRBIO	0.212	0.045	0.163
CPYCOV	-0.065	0.004	0.012
DECDCOV*	-0.552	**0.305**	-0.352
TRHT	0.227	0.051	0.149
CRHT	0.143	0.020	0.079
TREES	-0.046	0.002	-0.077
TREERICH	0.106	0.011	0.005
SNAGS	0.145	0.021	0.059
SGDBH	0.095	0.009	0.095
SNGHT	-0.088	0.008	-0.095
SGDECDIV	0.057	0.003	0.016
SGDECSTG	0.280	0.079	0.175
DWD	0.079	0.006	0.027
DWDDECCL	0.050	0.002	0.093
DWDDECDIV	0.039	0.001	0.039
VEGRICH	-0.262	0.069	-0.089
VEGCOV	-0.434	**0.189**	-0.277
SAPRICH	-0.018	0.000	-0.042
SAPBIO	-0.145	0.021	-0.089

Table 3. Significant indicator species of habitat type in The Evergreen State College forest reserve, Olympia, WA, using a Monte Carlo randomization test (1000 permutations).

Species	Observed indicator value (OIV)	OIV from randomized groups	St. Dev	P*
CAVI	27.3	10.3	6.09	0.045
WAVI	28.6	14.7	6.65	0.050
BCCH	38.3	23.2	6.38	0.030
CBCH	37.9	26.5	4.78	0.031
SWTH	35.3	29.3	3.30	0.046
SOSP	37.9	29.6	2.47	0.003

* proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
P = (1 + number of runs >= observed)/(1 + number of randomized runs)

Maxgrp = Group identifier for group with maximum observed IV

Table 4. Habitat relationships derived from linear regression analysis for avain community indices in the Evergreen State College forest reserve, Olympia, Washington, 2008 (n=88). Variable codes are defined in table 1.

Response variable	Predictor variable	Variation explained (adjusted R²)	F	P
BDIV	CPYGAP	0.043	2.910	0.100
	TREES	0.020	0.150	0.700
	TRBIO	0.001	1.050	0.310
	TRHT	0.004	0.820	0.370
	CRHT	0.010	1.480	0.230
	DECDCOV	0.010	1.500	0.230
	CPYCOV	0.020	1.900	0.170
	TREERICH	-0.010	0.430	0.510
BSR	CPYGAP	0.006	1.250	0.270
	TREES	-0.020	0.090	0.770
	TRBIO	-0.005	0.790	0.380
	TRHT	-0.004	0.810	0.370
	CRHT	0.010	1.450	0.230
	DECDCOV	0.070	4.430	0.040
	CPYCOV	0.020	1.700	0.200
	TREERICH	0.020	0.110	0.740
BAB	CPYGAP	-0.006	0.740	0.390
	TREES	-0.020	0.005	0.950
	TRBIO	0.003	1.130	0.290
	TRHT	0.030	2.100	0.150
	CRHT	0.020	1.770	0.190
	DECDCOV	0.320	21.400	<0.001
	CPYCOV	0.003	1.150	0.290
	TREERICH	-0.020	0.020	0.890
BDIV	SNAGS	0.070	4.400	0.040
	SGDBH	-0.020	0.030	0.870
	SGHT	-0.020	0.100	0.750
	SGDECDIV	0.070	4.090	0.050
	SGDECSTG	-0.020	0.050	0.820
BSR	SNAGS	0.140	8.040	0.007
	SGDBH	-0.020	0.100	0.750
	SGHT	-0.002	0.900	0.350
	SGDECDIV	0.120	7.100	0.010
	SGDECSTG	-0.020	0.250	0.620
BAB	SNAGS	0.100	6.030	0.020
	SGDBH	-0.020	0.300	0.580
	SGHT	0.010	1.530	0.220
	SGDECDIV	0.060	3.540	0.060
	SGDECSTG	-0.010	0.570	0.450
BDIV	DWD	0.006	1.300	0.270
	DWDDECDIV	-0.020	0.002	0.960
	DWDDECCL	-0.020	0.260	0.610
BSR	DWD	-0.020	1.910	0.170
	DWDDECDIV	-0.020	0.220	0.640
	DWDDECCL	-0.020	0.030	0.870
BAB	DWD	-0.010	0.410	0.520
	DWDDECDIV	-0.020	0.350	0.560
	DWDDECCL	-0.010	0.370	0.550
BDIV	VEGRICH	0.060	2.600	0.110
	VEGCOV	0.060	3.970	0.050
	SAPRICH	-0.006	0.730	0.400
	SAPBIO	0.160	9.180	0.004
BSR	VEGRICH	0.060	3.600	0.060
	VEGCOV	0.050	3.100	0.090
	SAPRICH	-0.020	0.100	0.760
	SAPBIO	0.110	6.180	0.020
BAB	VEGRICH	-0.004	0.830	0.370
	VEGCOV	-0.009	0.630	0.430
	SAPRICH	-0.012	0.490	0.490
	SAPBIO	0.004	1.170	0.290

Table 5. Model comparison results for abundance (BAB), bird species richness (BSR), and bird diversity (BDIV) for each habitat model examined in the Evergreen State College forest reserve, Olympia, WA. Variables with the lowest AIC were selected as the best model. Variable codes are listed in table 1.

		AIC*	
Variable	BAB	BSR	BDIV
Trees			
CPYGAP	173.39	79.20	-177.50
TRBIO	172.98	79.67	-175.63
CPYCOV	172.66	78.75	-176.51
DECDCOV	154.95	76.10	-176.10
TRHT	172.56	79.64	-175.40
CRHT	172.75	78.99	-176.07
TREES	174.16	80.39	-174.70
TREERICH	174.14	80.36	-175.00
Snags			
SNAGS	-200.27	16.40	-102.20
SGDBH	-202.31	16.86	-101.90
SNGHT	-200.34	17.12	-101.90
SGDECDIV	-201.55	12.37	-104.53
SGDECSTG	-201.65	17.81	-102.41
DWD			
DWD	-182.80	12.26	-93.24
DWDDECCL	-182.64	12.11	-93.70
DWDDECDIV	-186.25	11.58	-93.46
Understory			
VEGRICH	-211.90	38.54	-167.14
VEGCOV	-211.90	39.20	-168.00
SAPRICH	-213.60	41.26	-166.10
SAPBIO	-211.90	39.35	-170.16

*Akaike's information criterion (Akaike 1974)

Figures

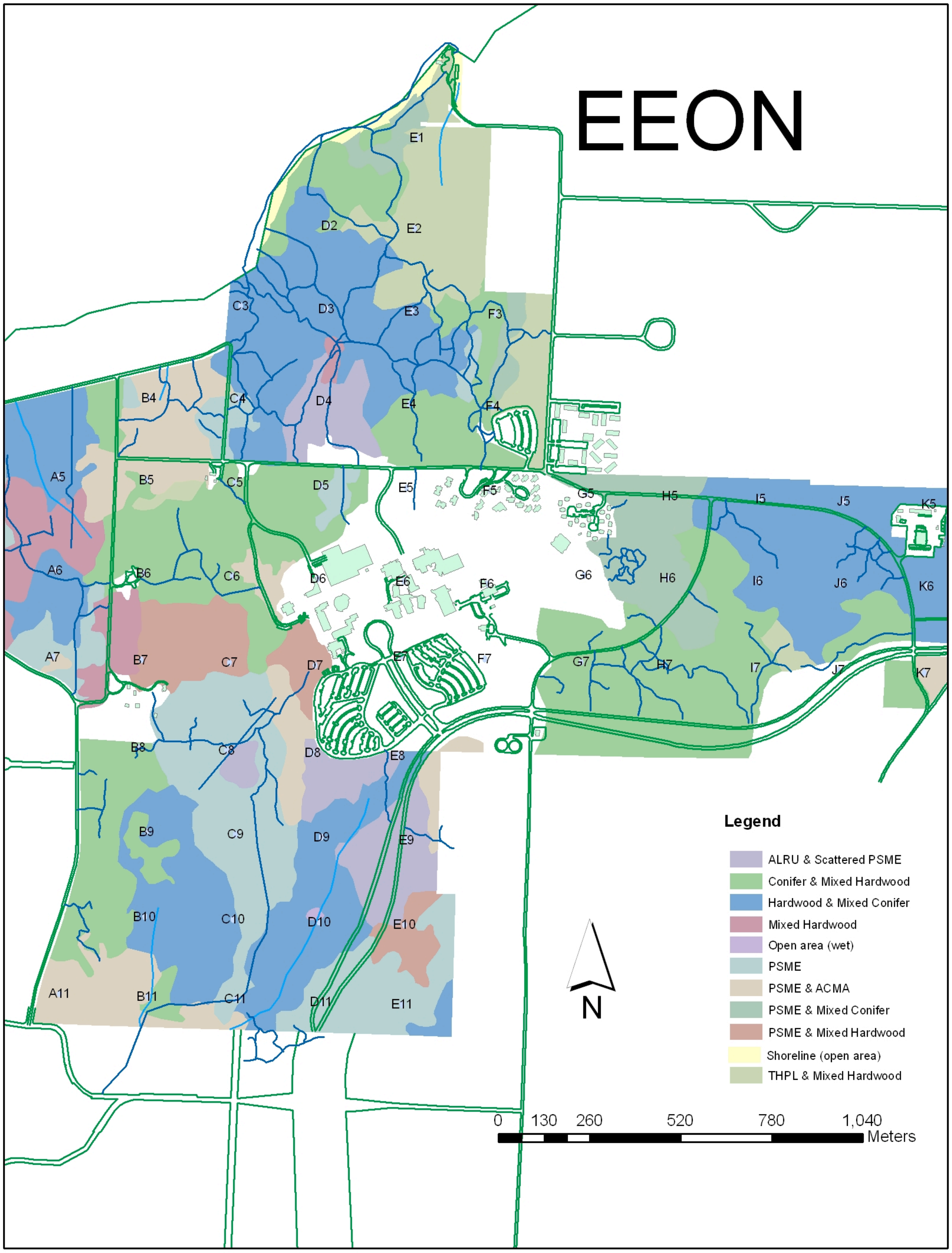


Figure 1. Map of EEON permanent forest plots showing nine different forest types across the reserve (Greenberg and Hartley, *unpublished data*). Forest types in this study were simplified into 1) Douglas-fir 2) mixed conifer 3) mixed conifer/hardwood 4) hardwood.

Figure 2a.1939 Orthophoto of the western half of future TESC property showing extensive land clearing (scanned and prepared by C. Adair)

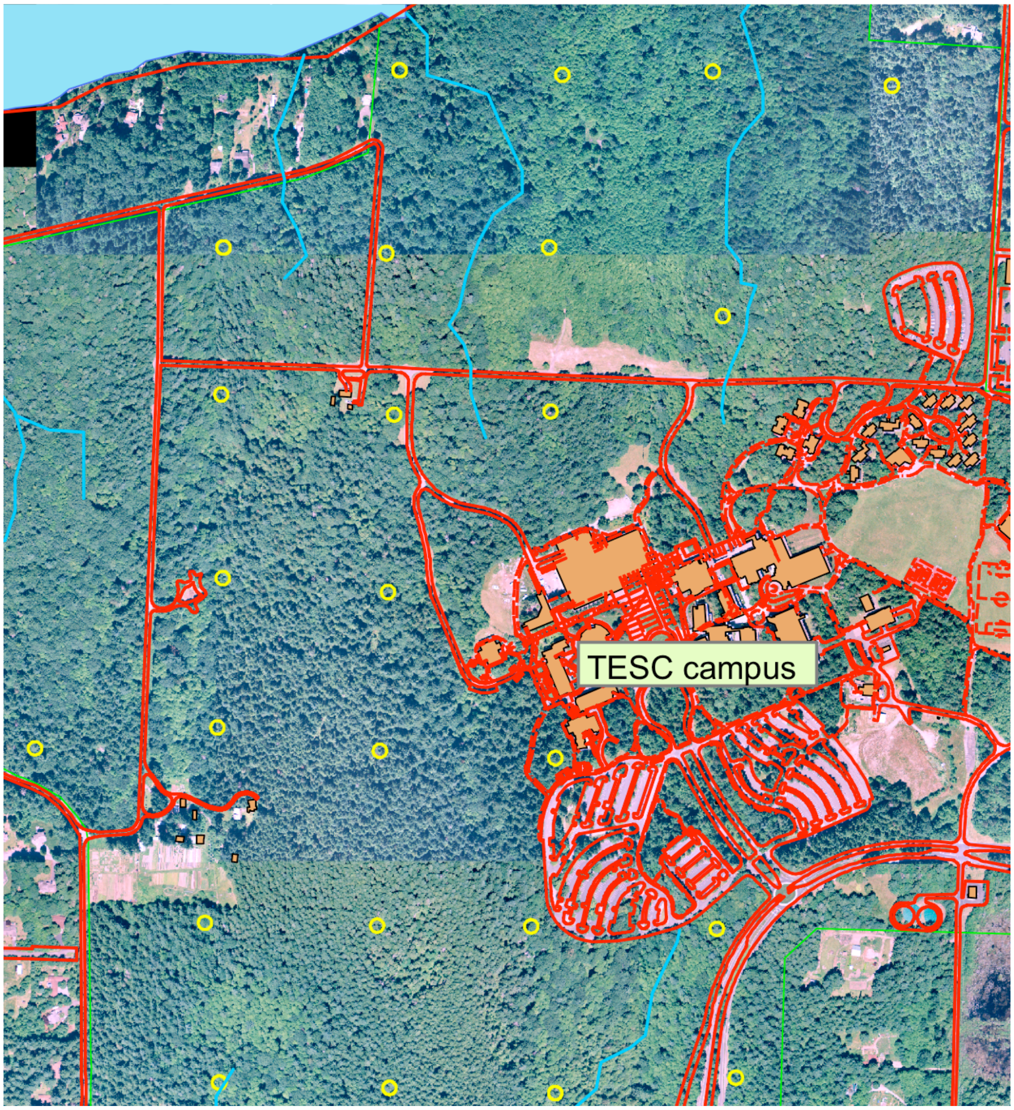


Figure 2b. Western half of TESC property as it looks today with large scale forest regeneration (http://academic.evergreen.edu/projects/EEON/, accessed April 11, 2009)

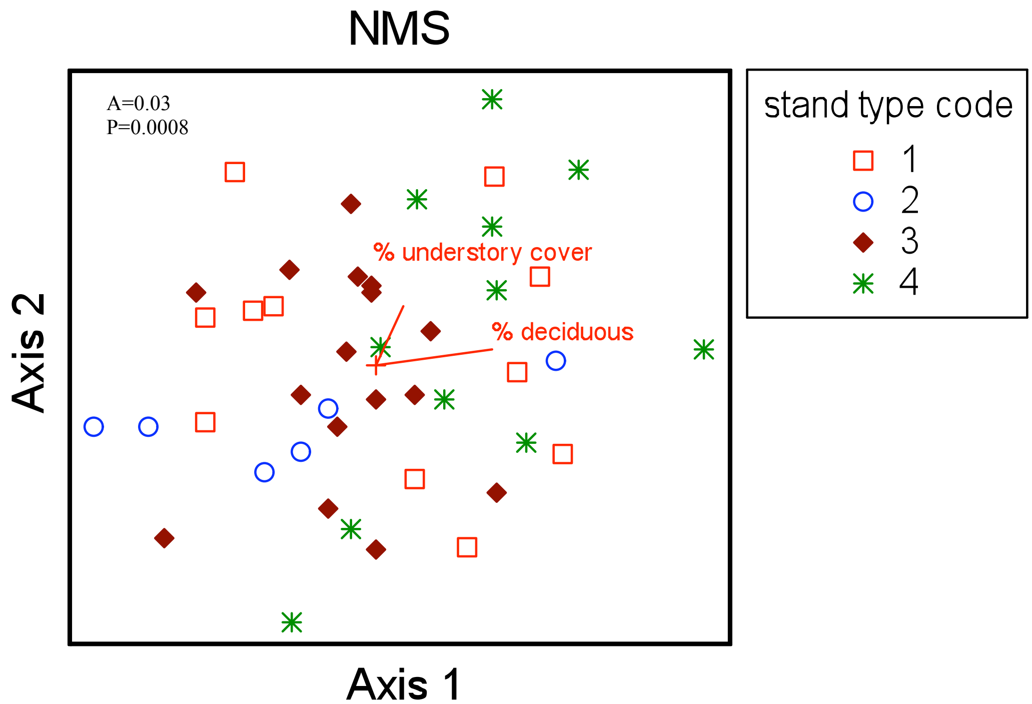
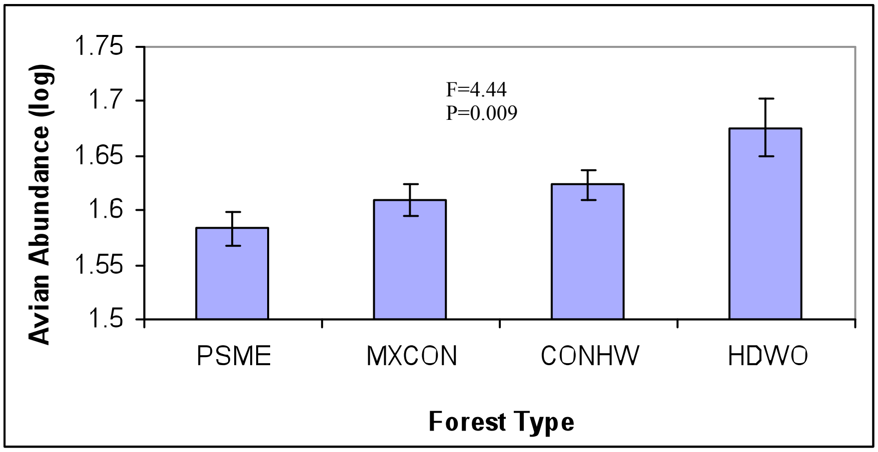
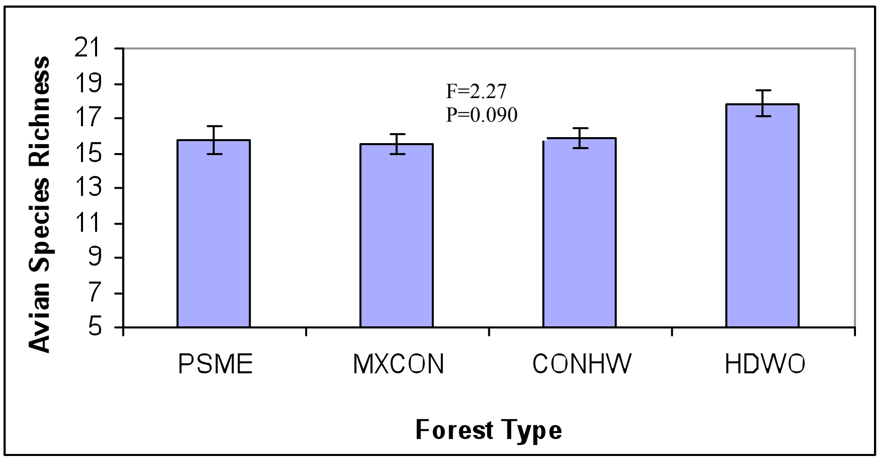


Figure 3. NMS Ordination of avian community composition for 4 different forest stand types, Douglas-fir (☐), mixed conifer (○), mixed conifer/mixed hardwood (◆), hardwood (✸) in The Evergreen State College forest reserve, MRPP A=0.03, P=0.0008. Bi-plot vectors show correlations of the matrix with percent deciduous cover (Pearson's r=0.261) and percent understory cover (Pearson's r=0.185).

A



B



C

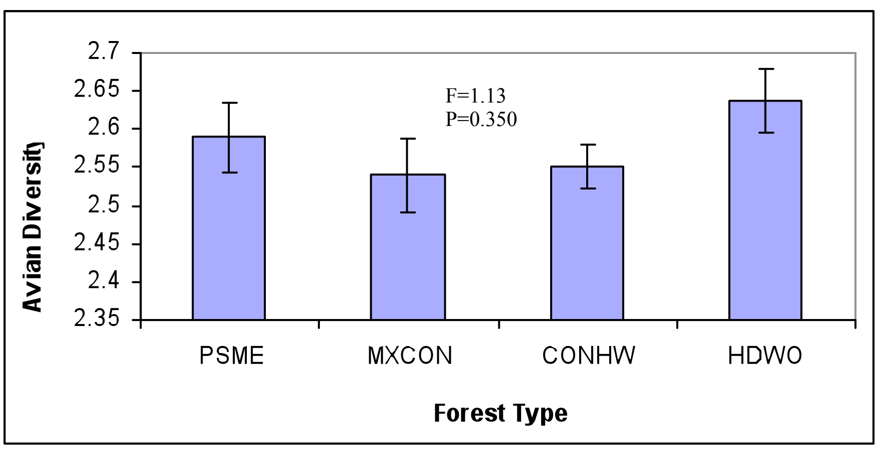
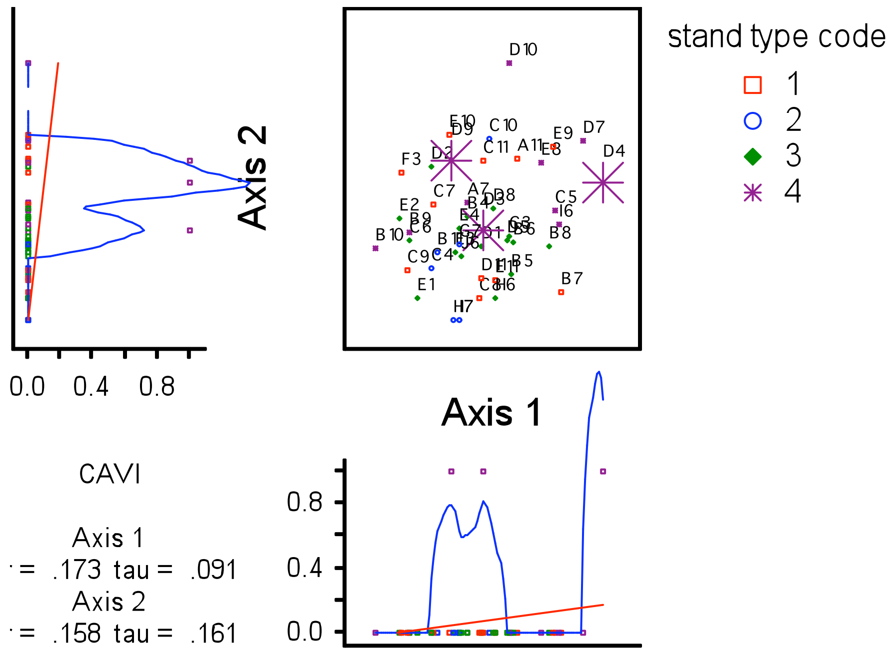


Figure 4. Comparison of avian a) abundance b) species richness and c) diversity (Shannon-Weaver) in four different forest types of the Evergreen State College forest reserve, Olympia, WA, 2008. Forest types are: PSME=Doug-fir, MXCON= mixed conifer, CONHW= conifer and hardwood, HDWO= hardwood. Analysis of variance revealed significant differences only in avian abundance. Post hoc tests (Tukey's HSD) revealed significant differences in hardwood. Error bars represent standard errors.


stand type code
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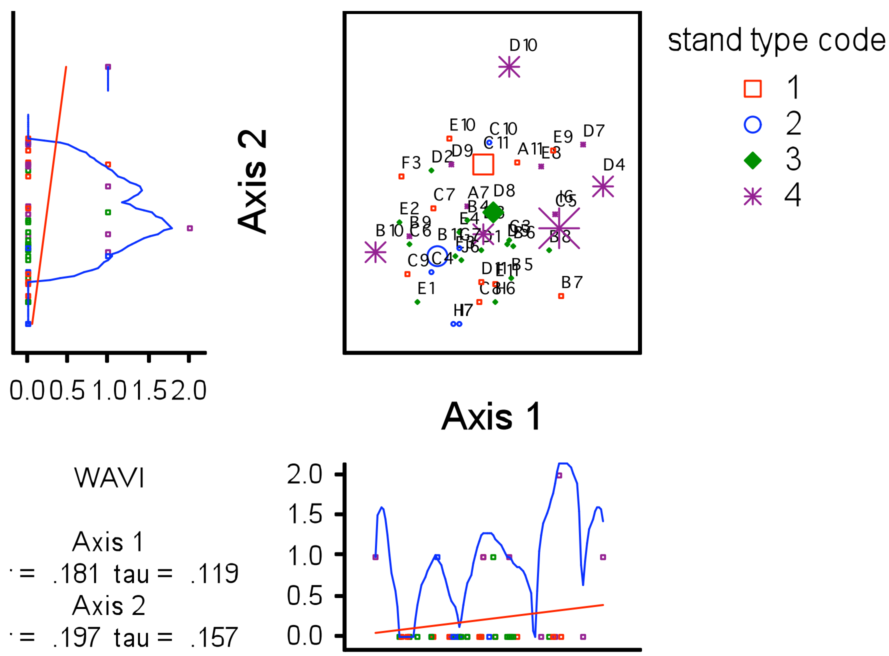
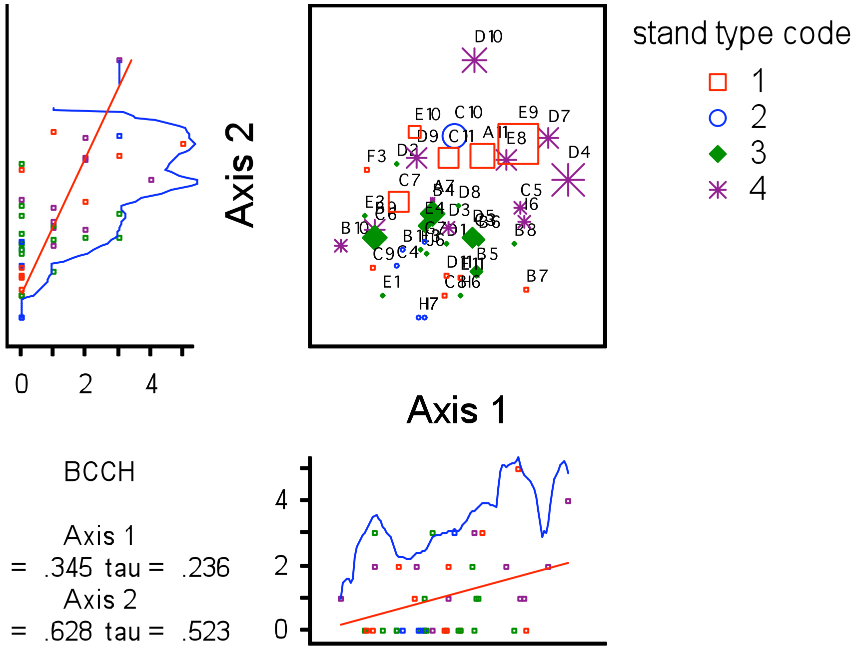
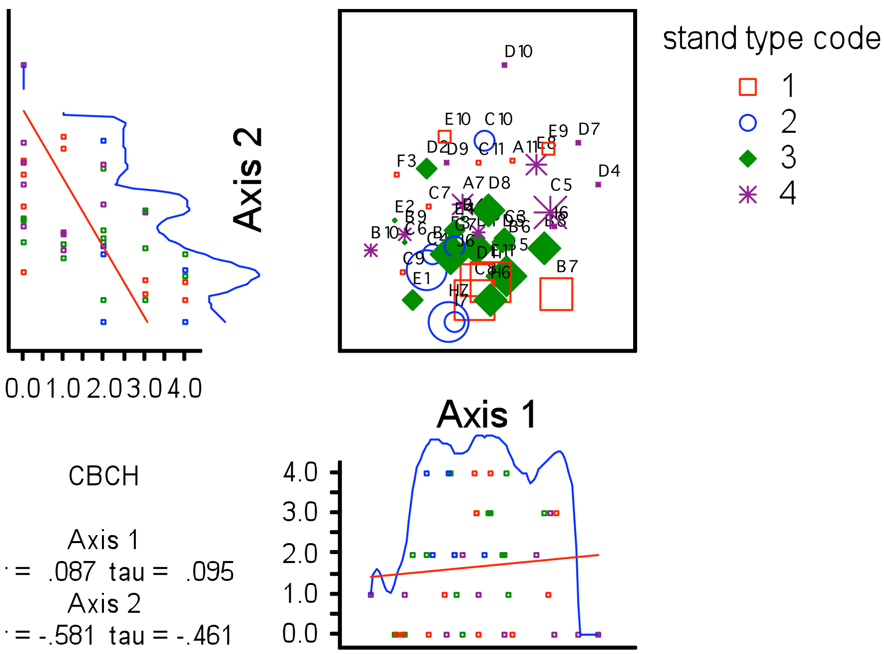
2
3
4
Axis 2
Axis 1
CAVI
Axis 1
r = .173 tau = .091
Axis 2
r = .158 tau = .161


stand type code
1
2
3
4
Axis 2
Axis 1
WAVI
Axis 1
r = .181 tau = .119
Axis 2
r = .197 tau = .157



Axis 2
stand type code
1
2
3
4
0
2
4
Axis 1
BCCH
Axis 1
= .345 tau = .236
Axis 2
= .628 tau = .523



Axis 2
stand type code
1
2
3
4
0.0 1.0 2.0 3.0 4.0
Axis 1
CBCH
Axis 1
= .087 tau = .095
Axis 2
= -.581 tau = -.461

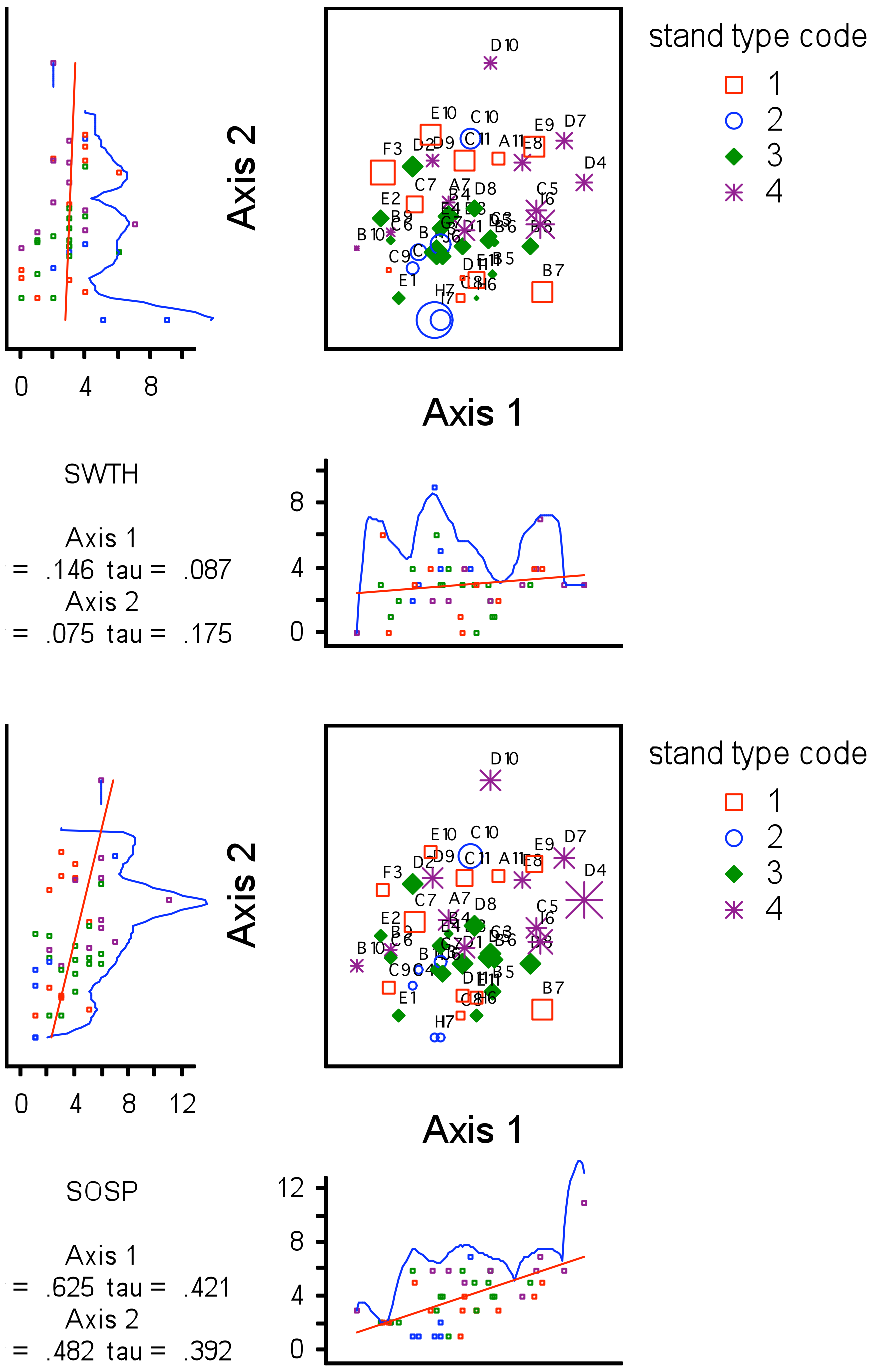
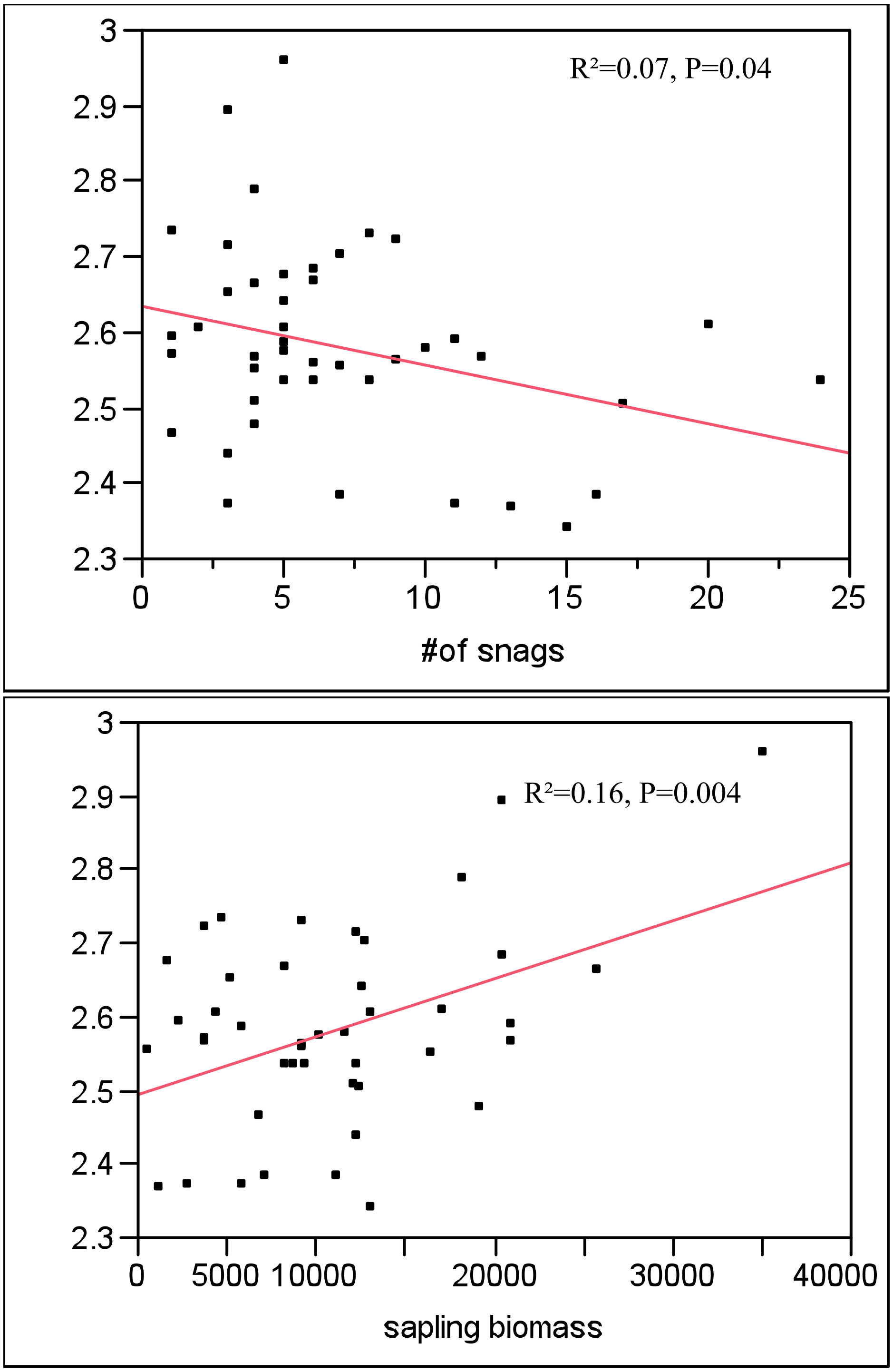
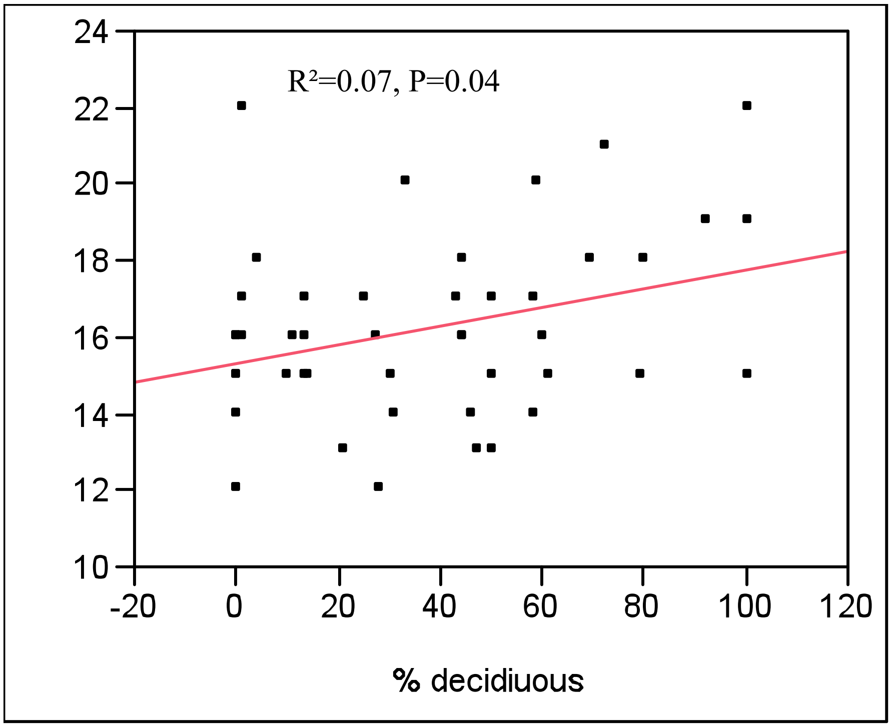


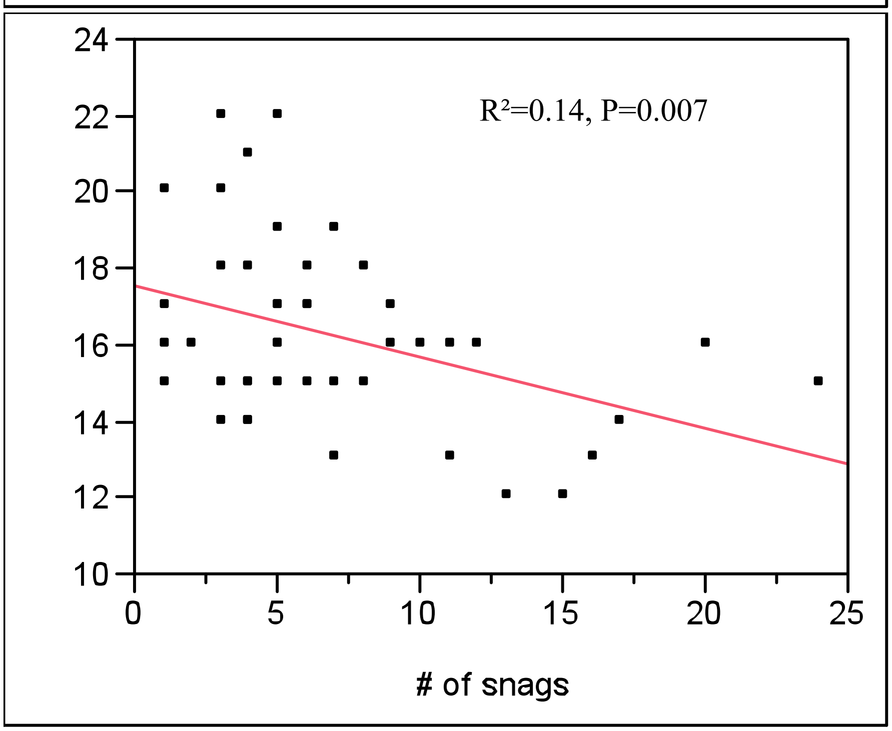
Figure 5. Graphical representations of NMS ordinations of species specific composition for 4 different forest stand types, Douglas-fir (□), mixed conifer (○), mixed conifer/mixed hardwood (◆), hardwood (✱) in the Evergreen State College forest reserve, Olympia, WA. Greater abundances of each species are represented by larger symbols on the ordination graph. Axis graphs show degree of correlation between each species' abundance and community similarity along each axis. Both species of Vireo, Black-capped chickadees and Song Sparrows appear to be indicators of hardwood stands. Chestnut-backed chickadees appear to be indicators of coniferous dominated stands.

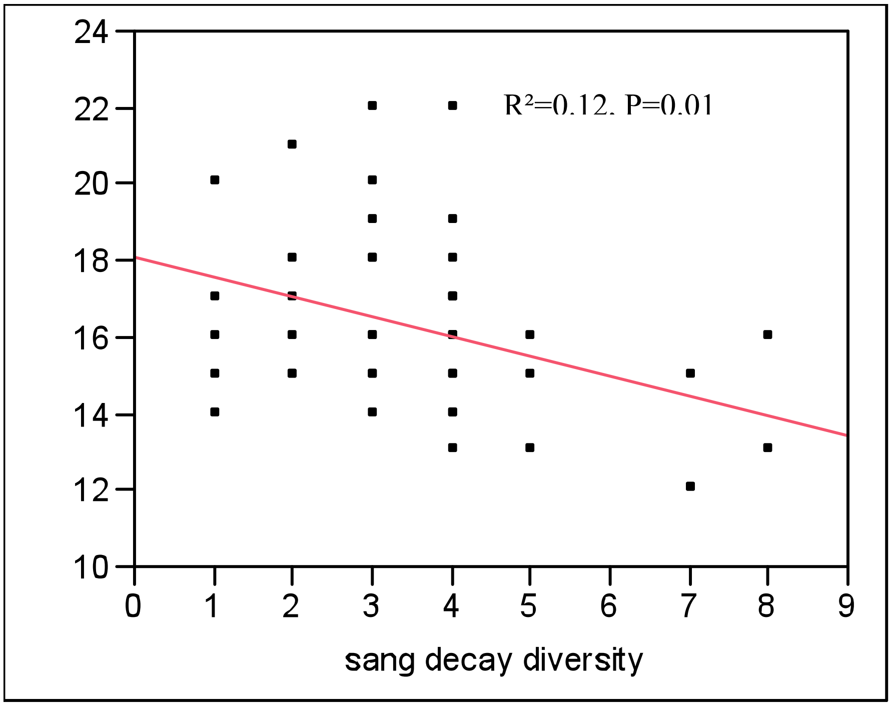
A) Avian diversity

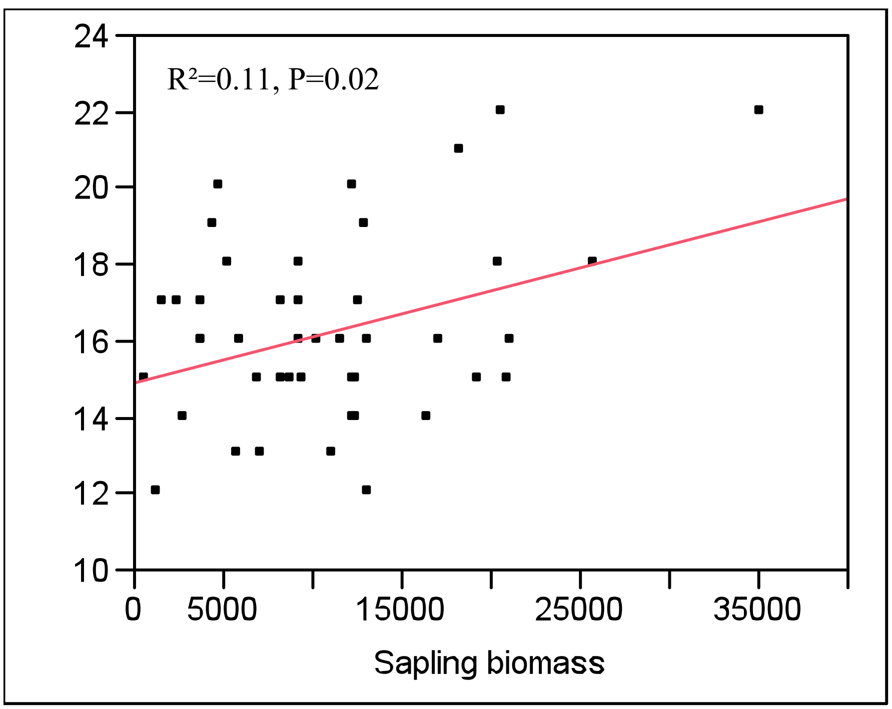


B) Avian species richness






R²=0.12, P=0.01
24
22
20
18
16
14
12
10
0 1 2 3 4 5 6 7 8 9
sang decay diversity


R²=0.11, P=0.02
24
22
20
18
16
14
12
10
0 5000 15000 25000 35000
Sapling biomass

C) Log avian abundance

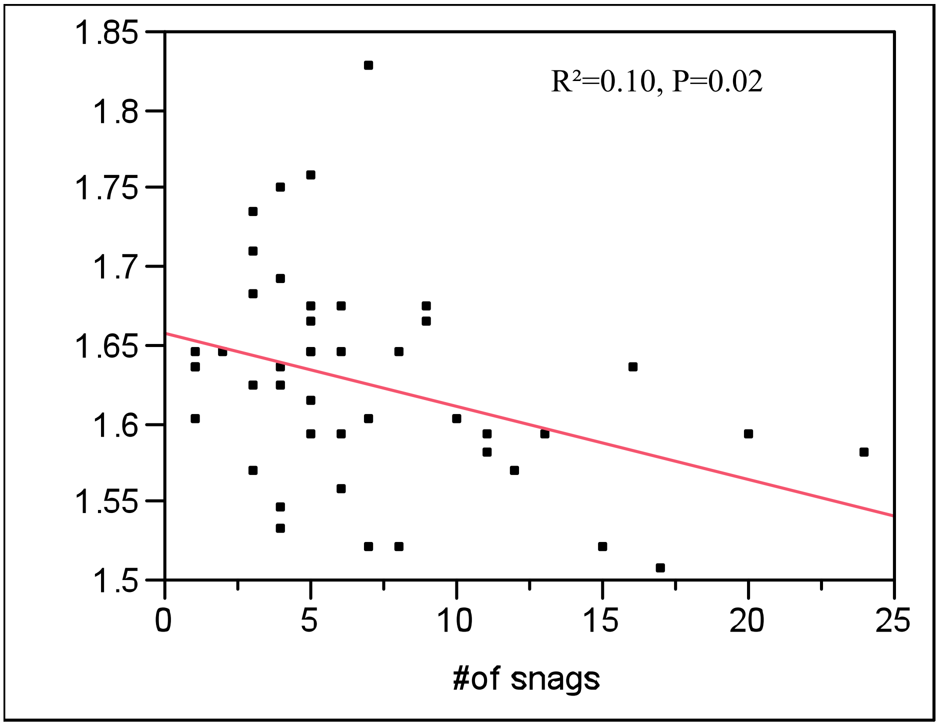


Figure 6. Significant habitat relationships based on regression models for community indices A) Avian diversity B) Avian species richness C) Log avian abundance. Snag density and snag decay stage diversity were negatively related to all community indices. Sapling biomass and percent deciduous cover explained the greatest variations in the bird community (R^2=0.15, R^2=0.11, R^2=0.32, respectively).

Chapter Three

Protocols and Research Recommendations for the Evergreen Avian Monitoring Program

In order to understand recent global declines in birds and to guide conservation efforts, long-term monitoring programs are necessary in conjunction with in depth species specific research. Increasingly, avian population monitoring is guiding the recovery of declining species and assisting initiatives to keep healthy population numbers steady. Many birds in the Pacific Northwest are also experiencing these declines, especially within lowland temperate rainforests which are under development pressure and may face ecological changes with a warming climate. The Evergreen State College's forest reserve offers an ideal setting in which to monitor populations of temperate rainforest birds, contributing to other long-term monitoring and conservation efforts. This chapter provides the necessary field protocols, tools and research considerations for EAMP to become a successful and effective component of the Evergreen curriculum and the larger south Puget Sound community. The protocol should be considered a working document with future additions and revisions made by students and faculty as the first years of monitoring are carried out and continuing contributions to the field of avian conservation are made.

3.1 Introduction

3.11 Monitoring

Long-term monitoring is widely used across the globe to understand population dynamics of birds (Marzluff and Sallabanks 1998, Ruth et al. 2003, Rich et al. 2004). Monitoring methodologies are based upon the objective they wish to achieve. Four common purposes and goals for monitoring are to: 1) show trends in populations over time at the landscape level (i.e the North American Breeding Bird Survey); 2) determine the influence of specific management actions; 3) conservation-oriented studies on reproductive success and survivorship; 4) determining the quality and quantity of habitat. Long-term population data that show trends over time are designed to identify significant or non-significant declines or increases in species within and among continental regions (Sauer et al. 2008). Usually spearheaded or run by governmental and academic groups, specific management actions or habitat conditions are assessed in relation to bird community responses (Ruggiero et al. 1991, Hansen et al. 1995, Young and Hutto 2002). Conservation minded non-profits such as Institute for Bird Populations (IBP) and PRBO Conservation Science conduct long-term monitoring of reproductive success and survivorship, usually through bird banding and nest searching methods.

Many successful monitoring programs link three types of data together to achieve an understanding of the bird community in a given area (Ralph et al. 1993). Successful monitoring programs bring together data on a) population size or trends of various species occupying habitat; b) the demographic parameters of these populations; and c) detailed habitat variables linked to the population and demographic data (Ralph et al. 1993). The newly created Evergreen Avian Monitoring Program (EAMP) will collect data on population trends of campus birds, reproductive success, survivorship and the habitat variables influencing this data. The objective of EAMP is to become a long-term monitoring program grounded in proven methods of data collection that can be replicated and shared with the greater scientific community, helping to identify declining species and understand the causes.

The sampling methodologies of EAMP are designed to complement the work of other programs and to provide comparisons within the Pacific Northwest region and beyond to other applicable regions. The 418 hectares that EAMP covers comprises a limited amount of habitats but will provide monitoring data for an area currently underrepresented in monitoring efforts (Battaglia 2000). Inferences can provide a localized assessment of bird populations as well as comparability to other regional projects. Initial results from EAMP work will identify patterns that need additional monitoring strategies and the development of hypothesis-driven research. Over time EAMP can assist other large and small scale programs in explaining bird population dynamics at local, regional and continental levels.

The methods of monitoring for EAMP follow the approaches of other well established programs across North America in habitats similar to our own (Martin and Geupel 1993, PRBO Conservation Science 2004, Siegel et al. 2004, Wilkerson et al. 2005). Because this is a long-term endeavor the population results for a wider variety of species, demographic data and habitat relationships will not be available for several more years. Typically results from avian research and monitoring programs are published after anywhere from 3-20 years of data collection. An important goal of EAMP is to collaborate with outside organizations and partners. One avenue for collaboration and data sharing is the Avian Knowledge Network (ANK), a relatively new online database which links hundreds of short and long-term avian datasets from around the continent (Avian Knowledge Network 2008).

3.12 Research and monitoring needs in Pacific Northwest forests

Research reviewed by Partner in Flight (PIF) of Washington indicates most reproductive studies at the community and landscape levels to be located in the Cascade Mountains and inland areas of Washington and Oregon (Rosenberg 2004). Few population, reproduction and behavioral bird studies cover the habitat of the Puget Sound basin's remaining temperate rainforests (Battaglia 2000). Furthermore, many bird/habitat studies occur on federal lands due to their size and diversity of habitats (Hansen et al. 1995, Anthony et al. 1996, Hagar et al. 1996, Weikel and Hayes 1999, Nott et al. 2005). PIF describes a need for data on reproductive success of focal species that can provide information on where source and sink habitats are occurring (Altman 1999). A wider array of western coniferous forest habitat needs to be included in monitoring efforts, at varying elevations and locations throughout the northern pacific rainforest region (Rosenberg 2004). Monitoring studies also require a broader range of research objectives, including everything from species-specific reproductive information to population changes at community and landscape scales (Rich et al. 2004, Rosenberg 2004).

In the past several decades ornithologists have begun to study the relationships between breeding, stopover and wintering grounds that influence bird conservation (Robbins et al. 1989). Documented declines in some species have not always been explained from breeding studies which has emphasized the importance of over-wintering and migratory stop-over studies (Plummer 2002, Rich et al. 2004). Current long-term, over-wintering studies are being conducted in areas of Latin America targeted at Neotropical migrants (Ralph et al. 2005, DeSante et al. In Press.) as well as the northern temperate zones for species which breed in northern boreal forest and tundra (Humple et al. 2001, PRBO Conservation Science 2004, Samuels et al. 2005) . The forests of Evergreen host 6 common species which spend the winter here and are candidates for over-wintering survival studies; Ruby-crowned Kinglet (*Regulus calendula*), Varied Thrush (*Ixoreus naevius*), Hermit Thrush (*Catharus guttatus*), Golden-crowned Sparrow (*Zonotrichia atricapilla)*, Fox Sparrow (*Passerella iliaca)*, and Lincoln's Sparrow (*Melospiza lincolnii)* (Wahl et al. 2005). Over-wintering studies could be carried out in conjunction with the already established Olympia area Christmas Bird Count (CBC) (National Audubon Society 2002). Taking CBC forest passerine data and applying it to productivity and survivorship data collected on campus via banding efforts will help elucidate the population dynamics and behavior of our wintering songbirds (particular sparrows which occur in high numbers and are easily caught in mist-nets). PRBO Conservation Science has operated a color-banded focal species project for over 20 years and tracks territories and survivorship throughout the year (PRBO Conservation Science 2004). Observers resight color-banded birds by routine area searches around the study site. Such monitoring has helped determine the success of restoration efforts in degraded riparian habitat while at the same time providing long term data on populations of resident and over-wintering species (Samuels et al. 2005). A pilot project of color banding resident and over-wintering species should take place in the future to assess the feasibility and resources required to carry out a color banding study on focal species (Ralph et al. 1993).

3.2 Focal Species: demographic monitoring

3.21 Productivity and Survivorship

Mist-netting involves capturing birds in mesh nets, banding them with a unique number sequence, and taking measurements and data on species, age, sex, breeding status, molt and physical condition (Pyle 1997). Mist-netting data provide indices of productivity through the assessment of adult breeding condition and analysis of juvenile to adult capture ratios (DeSante et al. 2008). In addition to USGS bands placed on each bird caught, in depth studies of focal species that are common and easily captured in mist-nets can contribute greatly to general knowledge of a species (Ralph et al. 1993). Life history studies now often involve the placement of a unique color-band sequence (3 colors plus the USGS required band) placed on the legs of individuals (Koronkiewicz et al. 2005). In addition to recapturing the bird in the mist-net throughout its life, color-banded individuals can be resighted unobtrusively with the aide of observers. Many successful color-banding projects augment survivorship data by resighting color-banded birds that are never again caught in a mist-net (Martin and Geupel 1993, PRBO Conservation Science 2004). Concurrently, monitoring can track individual territories and pairs throughout the breeding season. Resident species are excellent candidates for intensive life history studies because recapturing and/or resighting an individual is more likely (Martin and Geupel 1993, DeSante et al. 2008).

Examining conditions and habitats on wintering and migration grounds may help to reveal the causes for declines in many species (Robbins et al. 1989, Marzluff and

Sallabanks 1998). In addition to resident species, TESC has several species that return each winter before moving further north or into the mountains to breed (Ruby-crowned Kinglet (*Regulus calendula*), Varied Thrush (*Ixoreus naevius*), etc.). These species should not be overlooked in monitoring efforts (Rich et al. 2004) conducted by EAMP. Similarly mist-netting efforts can occur during fall and spring migration which can track arrival and departure dates of Neotropical breeding species over time as well as the extent and distribution of other species moving through the area (Root et al. 2003, Sparks et al. 2005). Migration net-netting will provide average arrival and departure dates to document avian responses to climate change (Root et al. 2003) and may be more feasible for the involvement of regular school year programs at TESC in the early stages of EAMP.

Banding methods assess the population health of only a small proportion of bird species in an area, usually about 10 species (Ralph et al. 1993). Permanent net locations with fixed flag poles can provide an opportunity to capture mid and upper canopy species with the use of stackable nets (Humphery et al. 1968). Otherwise there is the severe limitation of only sampling ground and understory associated species (Bonter et al. 2008). This is an addition that should be employed after mist-netting stations are operating comfortably as it is labor intensive and costly to implement (personal observation).

Information on survivorship and productivity indices are valuable but the data loses habitat specificity throughout the breeding season as adults birds disperse to feed young (Martin and Geupel 1993). For this reason mist-netting should be complimented with other monitoring methods, such as intensive point count surveys conducted at least twice during the breeding season, to account for birds that may have dispersed (Ralph et al. 1993). Surveys are conducted around the mist-netting station and should be completed at about the mid point of the 10 day interval between banding days (PRBO Conservation Science 2004). The use of intensive and extensive point counts are described below under protocols.

3.32 Nest searching

Nest searching techniques involve the establishment of intensive plots where an individual works to locate and track the development and outcome of each nest (Martin and Geupel 1993). Upon competition of the nesting attempt, the vegetation around the nest is measured along with that of a control area in representative habitat away from the nest (PRBO Conservation Science 2004). Nest searching is usually done between May and August and each nest is visited at least once every four days to check the status of the nest and record observations. Nest searching is labor and training intensive and applies to fewer species than mist-netting but provides a direct assessment of reproductive success and can elucidate rates and causes of predation and parasitism as well as basic breeding and nesting behavior (Martin and Geupel 1993).

Due to the high canopy and dense undergrowth found throughout the TESC forest reserve, directly locating nests of focal species will present difficulties. Resident species generally nest near or on the ground with excellent concealment (Ehrlich et al. 1988, Wahl et al. 2005). Observational approaches that indirectly confirm nesting activity and reproductive success may be a viable alternative for species that are particularly difficult to nest search for (Vickery et al. 1992). Such approaches use breeding behaviors linked to stages in the reproductive cycle to determine a pair's nesting status. Reproductive behaviors can be transformed into reproductive indices and used as measures of fitness (Mayfield 1961). Such tactics are used in a variety of situations where a species may be rare or endangered and nest disturbances during breeding may influence a population (Ralph et al. 1993)

Another indirect reproductive monitoring tool is documenting song types to indicate mated status of singing males. Although this approach does not confirm success or failure it indicates pairing or certain species in particular habitats, distinguishing paired species from non-paired ones. This may be important in certain habitats of TESC reserve that are connected to particular species such as cottonwood and willow stands in riparian areas of campus and warbling vireos (*Vireo gilvus)* (personal observation).

Alternatives to nest searching and monitoring should be considered only after an attempt to start a nest searching program over one season has been made (Ralph et al. 1993). After one or two pilot seasons of nest monitoring it will become clearer whether direct reproductive monitoring is a viable option for EAMP. If so few nests are located as to not support existing data or resources are limited for locating nests, further research on alternatives should be made along with recommendations for protocol changes. The nest monitoring protocols are included here in order to expedite a pilot project to assess its viability as a monitoring tool.

3.3 Protocols

3.31 Point counts

The continued collection of breeding bird survey data, as I have done in 2008 will be a vital component to the success of EAMP. Such surveys are known as extensive point counts because they cover an entire study area (Ralph et al. 1993). Extensive surveys remain the primary method for monitoring population changes in forest birds (PRBO Conservation Science 2004). Each year a minimum of one survey should be completed in each plot of EEON (Buskirk and McDonald 1995, Siegel et al. 2001). Yearly point counts will enable EAMP to assess changes in populations in fixed locations and habitats (permanent plots within the network), the differences in population changes and species composition between habitats, and the how population trends change over time. In conjunction with mist netting and banding, intensive point counts located around the nets at each station should follow the same protocols described below except there should be a minimum of two surveys spread out over the banding season. Current monitoring programs do intensive point counts at stations early, mid and late in the breeding season) (Ralph et al. 1993, Siegel et al. 2001).

In order to calculate absolute abundances of birds each year, EAMP protocols use a variable circular plot (VCP) point count method where the distance is recorded from the observer to each bird heard or seen (Reynolds et al. 1980). Although the detection radius is theoretically infinite, studies have shown that 99% of birds are detected within 125 meters of the observer (Reynolds et al. 1980). In temperate North America the survey period should run during the height of the breeding season when detection rates are most stable (Ralph et al. 1993, Siegel et al. 2001). In Western Washington at low elevations this is generally the beginning of May into the beginning of July (Barrier and Froyalde 1999).

Although there are varying point count protocols EAMP follows the methodologies of long term monitoring programs such as Point Reyes Bird Observatory (PRBO) and Institute for Bird Populations (IBP). Counts should begin approximately 15 minutes after local sunrise and should be completed before 10am, usually within 3-4 hours (Ralph et al. 1993, Ralph et al. 1995) . Counts should not be conducted if weather conditions possibly could reduce detection of birds. Winds above 10 mph, continuous rain or extreme temperatures warrant cancelling a count. At each point record the general weather conditions, with temperature, cloud cover and wind speed, plot name, starting time (24 hour clock) and noise level (road or construction are common on campus). A sample data sheet derived from PRBO Conservation Science (2004) for VCP counts is provided in Appendix C.

At each point, approach the point quietly, minimizing disturbance. If disturbance is unavoidable, wait 2-5 minutes quietly for activity to resume to normal. If a bird was flushed within 10 meters of the point when you arrived, include it in the count. Set your watch to five minutes and begin the count once you are ready to record. If noise or another disturbance interrupts the count, cross out the survey, note the disturbance, wait until it passes and begin the survey again. All surveys should last five minutes with detections divided into the first three and the last two minutes of the survey (Ralph et al. 1995). Record every species detected regardless of distance, with the appropriate four letter AOU code (American Ornithologists' Union 2008). For unknown species enter XXXX. If the group of bird is known substitute the last two letters for that group. For example, enter XXFL for an unknown flycatcher. Unidentified birds should be followed and identified if time permits. If no birds are detected at a point make a note on the data sheet. For each detection also record the distance to the bird when it was first detected to the nearest meter and the type of identification used as S-song, C-call or V-visual (PRBO Conservation Science 2004). Other less common types are D for drumming woodpecker and H for humming hummingbird. If a bird is in flight or high in a tree when it is detected record the distance the bird would be if it were on the ground directly below it (Buckland et al. 2001). Birds flying over but not using the habitat are not recorded but should be noted in the field journal to assist with long-term natural history observations and an updated species list for the college. Record any breeding activity observed as follows (PRBO Conservation Science 2004):

CO- copulation

TD- territorial display

DD- distraction display

FC- food carry

FL- fledgling(s) observed

FS- fecal sac carry

MC- material carry

NF- nest found

PA- pair

A hardcopy datasheet should exist for every point count conducted, photocopied and stored in the lab. Ideally all data should be entered the same day as the survey to reduce errors and make necessary corrections while the field day is fresh in your mind. When a datasheet is entered the date and your initials should be written on the bottom of the hardcopy. If time allows datasheets should be proofed with two people before the end of the season and the date and initials noted again on the sheet (PRBO Conservation Science 2004).

Adequate training in bird identification by observation, song and call is imperative to the success of any monitoring program (Ralph et al. 1995, Wilkerson et al. 2005). Each surveyor should learn the songs and calls of all western forest bird species with the aid of audio devices and computer software (around 90 species) (Wahl et al. 2005). Learning how to use rangefinders effectively and estimate distances requires experience and practice. Observers should begin practicing by estimating the distance to known objects such as flagging and checking afterwards with the rangefinders (Siegel et al. 2004, Wilkerson et al. 2005). Afterwards the surveyor should practice counts in the early breeding season when resident species have begun to sing. The point counter(s) for each year should help the program's continuation by advertising, recruiting and training a point counter(s) for the following breeding season.

3.32 Nest searching and monitoring

Nest monitoring is a helpful component to any avian monitoring program because it provides data on nesting success or failure, trends in recruitment and natural history information that may be lacking or incomplete for many species (Martin and Geupel 1993). For most programs nests are located for color-banded individuals. One or both of the parents will be identifiable and can be tracked through the breeding season. If a nest is successful the nestlings can be color-banded just before they fledge in order to continue identifying individual pairs in coming breeding seasons (PRBO Conservation Science 2004). A reasonable start to a nest monitoring program at TESC would be to locate the nests of color-banded individuals around the organic farm banding station (figure 1).

Nest searching and monitoring is a particularly invasive methodology with potential impacts that should be minimized at all times (Martin and Geupel 1993). PRBO has put together a list of nest searching rules and have been amended here for our study area (PRBO Conservation Science 2004):

1) Distress calling by adults should never continue for more than 5 minutes. If the nest cannot be located return on a different day.

2) Do not approach a nest or attempt to locate a nest you know is close by if a corvid is present (jays, ravens or crows).
3) When checking or locating a nest never leave a dead end trail to the nest. "Fake" check other bushes and trees and make other trails in the area.
4) Minimize impact to the vegetation around the nest
5) Do not take others to see the nest. Only the person monitoring the nest should know where it is located.
6) Use a pen or stick to check the status of a nest so as not to leave your scent around the nest.
7) Move in and out of the nest area quickly when checking a nest, complete datasheets when away from the nest.
8) Never use flagging or other visual aids to mark a nest location. If a general area must be flagged flag at least 50 meters away from the nest and write the cardinal direction to the nest, date and nest number on the flagging. Remove all flagging after the nest is no longer in use.
9) After finding a nest, GPS its approximant location, memorize the location and write down a detailed description of how to reach it again.

The life history traits of many North American species are poorly understood, stemming mostly from the misconception that nests are too difficult to find (Martin and Geupel 1993). When learning to nest search it is helpful to read existing natural history and nest strategies of the focal species. The Birds of North America series offers detailed accounts of every avian species breeding in North America (Poole 2005). A good understanding of behavioral cues seen around nest sites, which comes from practice, is also an important factor to successfully locating nests (Martin and Geupel 1993). Most people can begin to locate nests on their own with a few days of practice and watching others locate nests. For example, during the 2008 breeding season while conducting point counts, I located the nests or saw material or food carries for 27 different avian species (Table 1).

For resident species in the lowland Puget Sound such as sparrows and wrens, nest construction may begin as early as late March (Wahl et al. 2005). With some exceptions such as wrens and woodpeckers the female of most species builds the nest and incubates the eggs (Ehrlich et al. 1988). For this reason locating and following the activities of the female is the most effective method for locating a nest (Martin and Geupel 1993). A mated female will exhibit specific behavioral towards her male partner including rapid movement around the male with no harassment, and food or copulation begging. Every effort should be made to locate a nest during construction to obtain complete nesting data (Mayfield 1975) and minimize disturbance (PRBO Conservation Science 2004). During nest construction females will carry material in the beak, often with long direct flights to the or near the nest location (Martin and Geupel 1993). Material is not often seen with the naked eye and a good pair of 7 or 8x42 binoculars are essential to seeing fine material such as spider web, lichen or flower seed (personal observation). Locating the source of nesting material and watching birds come and go is recommended. Once a material carry is seen follow the bird visually. If the bird disappears into nearby vegetation wait for the bird to return for more material. Several trips to and from the same location may help confirm the general location of a nest. If the observer is to close to the nest a bird will often sit above or nearby the nest nervously until the observer leaves (PRBO Conservation Science 2004). If this occurs or a bird drops nest material, move away quickly and relocate. Once the area of the nest site has been identified return later to locate the exact location when the female is not present. Checking for the nest right away while the female is watching can cause abandonment (Martin and Geupel 1993).

During egg laying, females generally lay one egg a day and may only visit the nest at that time (Martin and Geupel 1993). Visits and incubation will become more frequent as more eggs are laid. To locate nests during egg laying use behavioral cues. Both birds will often look at the nest when they arrive. Females staying in one area without feeding can indicate a nest nearby. Copulation will occur for each egg laid and generally occurs above, at or very near the nest. The completion of egg laying and the beginning of incubation is easily identified by increased singing by the male and difficult detection of the female. If a female is located and moving and foraging very quickly for short periods of time she will probably return to the nest soon. Most passerines incubate for 20-30 minutes and feed for 6-10 minutes (Gill 2006). Following a foraging female for 30 minutes may indicate she is not incubating. Incubating females will be generally conspicuous when foraging but more cautious as they near the nest (Martin and Geupel 1993).

The nestling stage is the easiest time to locate nests (Ralph et al. 1993) but provides the least amount of data (Mayfield 1961). Both parents will feed young and remove fecal sacs from the nest, increasing trips to and from the nest site. Parents will be particularly vocal with frequent distress calling if you are near the nest (PRBO Conservation Science 2004). Locating nests in this stage from far away should be done to eliminate distress calling or interruptions in feeding.

Once a nest is located a nest card should be filled out (Appendix C) and the nest checked every 2-4 days depending on the nesting stage (PRBO Conservation Science

2004). The nest card shown in the appendix of this chapter or its equivalent should be used for data comparison to other nest monitoring projects. Earlier in the nesting period nest should be checked less frequently, while later when nestlings are near fledgling age the nest should be checked more often to get a reliable or exact date of nest success or failure (Mayfield 1961). Ideally, nest cards should include the date of the first egg laid, the clutch completion date, hatch date, and fledge or fail date. Determining the nest outcome is one of the most important aspects of nest monitoring (Mayfield 1961;1975). The date determination of at least one of these major nesting events allows you to determine the nest age by counting backwards using existing natural history species accounts. Knowing the nest age provides statistical estimates of the probability of nest survivorship for each species (Bart and Robson 1982). Clearly describe each visit on the nest card, the date, parent or young behavior and the status of the nest. Prior to the breeding season a cheat sheet outlining the life history attributes for each species can be helpful in the field (PRBO Conservation Science 2004). This will help observers determine nesting events such as hatching date (Martin and Geupel 1993). Metadata on recording nest data and an example of a nest card can be found in Appendix C.

When the nest becomes inactive, measurements of the nest and the surrounding vegetation should be taken. This allows for nest success or failure to be linked to nest site selection and habitat variables (PRBO Conservation Science 2004). Generally protocols for vegetation measurements involve measuring the nest itself, the plant the nest is in and the vegetation within a 1.5 meter radius around the nest. Data on the cover and height of all shrub, forb and tree species should be collected. Vegetation protocols should be developed during the planning phases of nest monitoring after several field trials to determine what data is most time efficient to collect while providing the most amount of information (Martin and Geupel 1993). The PRBO terrestrial monitoring handbook provides a detailed example of vegetation protocol (PRBO Conservation Science 2004).

Most nest monitoring programs utilize a statistical analysis known as the Mayfield Method to estimate nesting success for focal species (Mayfield 1961). The number of days that a nest has eggs or nestlings is used to calculate daily mortality rates and generate nesting success models for species (Mayfield 1961;1975, Hensler and Nichols 1981). Various data entry and analysis software exist using the Mayfield Method and should be researched during the planning stages of this monitoring component (see the California Avian Data Center at: http://data.prbo.org/cadc2/index.php?page=songbird-nest-observations).

3.33 Mist netting and banding

Minimum protocol suggests an operation of 8-12 nets open at least once every ten days between May and August (Ralph et al. 1993), however a pilot project for demographic work may be necessary to determine the best start date. Ralph et al. (1993) recommend May 1- August 28 for most of temperate North America, however local weather and climate play a critical role. A sampling interval of ten days allows for at least one make up weekend in the case of inclement weather, divides each month of the season into equal proportions, and provides a direct comparison to other locations (PRBO Conservation Science 2004). Nets should not be opened in extreme moisture (usually morning fog), rain, wind or excessive heat or cold. Nets should be closed if any of these situations develop or in the event of bird predation in the net or a predator intently watching a net (DeSante et al. 2008). Pilot banding under classes at TESC have occurred at the campus organic farm (Figure 1a) and a tentative net locations have been mapped (Figure 1b). This area is at the interface of a variety of habitats, has net lanes cleared and reliably catches birds. So far banding has occurred over various seasons.

There should be a minimum of two experienced banders operating the nets at all times, with initial opening 15 minutes after local sunrise (Ralph et al. 1993). Net checks should be done every 30-40 minutes in ideal weather conditions, and move often if weather is cold or hot (DeSante et al. 2008). Each bird caught should be placed in an individual cotton bag and brought immediately back to the lab for banding once the net checks are complete. Bags should be washed regularly to reduce the spread of avian diseases (PRBO Conservation Science 2004). Nets should be closed 5-6 hours after you opened the first net depending on how many net hours we wish to obtain (Ralph et al. 1993). Always record how long each net was open in the net hours log found in the banding book. Also record total net hours in the banding journal located at the back of the banding book. The journal entry each day should include a description of activities and participants, time of net opening and closing, and a banding summary include species, sexes and ago groups (PRBO Conservation Science 2004). Protocols for collecting bird data during banding is outlined in the Identification Guide to North American Birds: Part I (Pyle 1997). Blank and example datasheets with metadata can be found in the Appendix C.

3.4 Monitoring Nocturnal species

Point count protocols adequately sample diurnal landbirds and are especially useful in forested habitats (Ralph et al. 1995, Bibby et al. 2000). Nocturnal landbirds such as owls however, require separate protocols which address life history, behavior and reliable detection rates (Johnsgard 2002). Owl surveys are generally conducted via playback of common calls given by the species surveyed for (Forsman 1983). A survey route is predetermined in a given area with fixed call locations established randomly with equal distance apart (Takats et al. 2001). Currently these points are not set up but should occur outside EEON plots in order to minimize site impact. Here I describe methods used under the Guidelines for Nocturnal Owl Monitoring in North America (Takats et al. 2001). Surveys begin within 30 minutes after local sunset and continue until completed. Surveys are conducted for 10 minutes at each station with calls given for 2 minutes followed by 2 minutes of listening for a response. Each survey begins with 2 minutes of silent listening before playback to allow data to be compared across the continent regardless of playback protocols used (Takats et al. 2001). If you hear an owl note down the species, which minute it was heard in (first, second or both) and estimate the distance and direction to the bird. If Great Horned Owls (*Bubo virginianus*) are heard at any time at a station, the survey at that station is discontinued. Great Horned's are known to displace and sometimes predate other owl species (Houston et al. 1998). All nocturnal species that respond are recorded. Focal species to survey for are to be determined but will probably include Barred Owl (*Strix varia*), Western Screech Owl (*Megascops kennicottii)*, and Great Horned Owl (*Bubo virginianus*). Protocols may vary for each species based on proven detection methods (Takats et al. 2001). The collection of data on nocturnal species will depend on student and faculty interest and should be considered with other monitoring priorities in mind.

3.5 Monitoring birds of the nearshore environment

The Evergreen State College campus comprises 3,300 feet of shoreline on Eld Inlet, Puget Sound (Zimmer Gunsul Frasca Architects 2008). The nearshore environment is an important component to the campus ecology and supports many avian species (Appendix A). A variety of seabirds make the Puget Sound their home in the non-breeding season and can easily be observed from the campus beach. Seabirds are top predators feeding on other marine organisms (shellfish and fish) and can aid in predictions of commercial fishery stocks (Cairns 1992). The Puget Sound Assessment and Monitoring Program (PSAMP) indicates nearly all seabird species wintering in Puget Sound are declined since 1979 (Seattle Audubon Society 2008). However, due to differences in past seabird survey protocols, discrepancies in population trend data have occurred. Seattle Audubon is developing partnerships for monitoring in South Puget Sound where population trends in seabirds are currently unknown (Seattle Audubon Society 2008).

The Puget Sound Seabird Survey occurs once a month from October to April. Surveys are 15-30 minutes in duration during a four hour window with the high tide (2 hours before high tide to 2 hours after high tide). All birds on the water within 300 meters of the shoreline are recorded with the aid of binoculars and spotting scopes. The directional bearing from the observer to the bird is recorded along with the distance from the horizon to the bird (in millimeters with a ruler). These distances allow individual seabirds present but not detected to be included in abundance estimates (Buckland et al. 2001) since diving birds under water will often be missed (Seattle Audubon Society 2008). Large rafts (flocks) of seabirds are counted with a clicker counter and the distance and bearing are taken from the middle of the raft. If monitoring the avian community of the shoreline and Eld Inlet follows PSSS protocols, EAMP can provide standardized data to Seattle Audubon and other seabird conservation organizations.

3.6 Recommendations for future projects

In addition to the monitoring work and potential studies I have presented above, there are many opportunities for individual student research projects through the structure of quarter long undergraduate projects linked to 16 credit programs, individual learning contacts, and Master of Environmental Studies (MES) theses. One benefit of an existing large ecological dataset and the establishment of a permanent plot network is that students may pursue their own interests from a large range of possible projects. Some examples of individual and group projects over varying lengths of time are described below with potential research questions.

Distribution and abundance of cavity dependent birds

TESC supports over a dozen cavity dependent species (Appendix D). Snags of varying sizes and decay classes are found in nearly every plot on campus (Appendix D). Recent wildlife management studies with snags suggest that snag quality (possessing characteristics necessary for cavity excavation) may be more important than snag abundance which has been the typical habitat management strategy (Cline et al. 1980, Bull et al. 1997, Smith et al. 2008). Cavity presence in snags and its influence on the cavity nesting species has not been examined in Puget Sound lowland rainforests. In hardwood forests of eastern North America, cavity presence in snags is positively correlated to DBH and decay class (Smith et al. 2008). Does an increase in snag and cavity availability increase abundance of snag dependent birds? What are the best predictors of cavity presence in snags?

Avian use in experimental cottonwood plots

Small pockets of mature cottonwoods exist in several areas of campus (personal observation, appendix B). These stands are sometimes near a permanent plot, but no cottonwoods are found in any of plots themselves. Deciduous trees are limited on campus and may influence the abundance of some songbirds (Hansen et al. 1995, Altman and Hagar 2007). Many studies involving cottonwoods and birds occur in riparian habitats, especially arid environments of the southwest (Johnson et al 1977). Cottonwoods on campus occasionally occur outside of riparian habitat because of the extremely wet environment. A nursery of young cottonwoods are ready for planting and could assist in an experimental study of avian use in cottonwoods on campus. Does the presence of cottonwood in lowland temperature rainforests influence the avian community? What is the role of cottonwood in patterns of avian diversity, abundance and nesting success?

Comparative breeding bird studies to low elevation Capitol State Forest stands

The 90,000 acre Capitol State Forest (CSF) has been owned and managed by the Department of Natural Resources since 1957 (Felt 1975). The close proximity and similar ecology to the TESC forest reserve provides the opportunity to conduct comparative bird studies on forest structure and avian habitat use. This work would constitute one of the few comparative avian studies to occur in low elevation rainforests of the Puget Sound. For example, a one quarter project with the addition of point count data from CSF could determine how 400 hectares of managed land at CSF compares to the same amount of unmanaged land at Evergreen.

Incorporation data into the Avian Knowledge Network (AKN) database

AKN holds data from over 400,000 locations, mostly in forested environments (Avian Knowledge Network 2008), and allows a student to work with large online datasets and hypothesis generation. A student would gain skills in generating viable hypotheses working with raw avian datasets and engaging in their statistical analysis. There is a need for a student to manage the existing data from EAMP and coordinate with AKN staff to upload our own data into the network.

3.7 Education and Outreach

3.71 Importance and need

In order for EAMP and bird conservation in general to be successful the message must be communicated to a broad audience outside of the academic and scientific community (Ruth et al. 2003, PRBO Conservation Science 2004). The general public, policy makers, landowners, children of all ages are all excellent targets for outreach. TESC has a long legacy of community involvement through events such as Super Saturday, work study internship arrangements with local businesses and non-profits, and a local and independent radio station. With such a relationship already established it is both productive and feasible for EAMP to develop education and outreach projects along with its scientific ones. The use of newspaper articles, radio/TV features, workshops, bird festivals, demonstration sites, and school activities have proven to be very effective for many bird observatories and long-term programs (Zack 2002, PRBO Conservation Science 2004). Education and outreach can be facilitated through TESC's existing relationships with community organizations such as Black Hills Audubon Society (BHAS) and The Nature Conservancy of Washington, and future partners such as the

Puget Sound Bird Observatory (PSBO).

3.72 Interpretation

Interpretation within the forested parts of campus is an excellent way to disseminate key concepts of the ecology of our forest, including the bird life. Displays, and information kiosks located along heavily used sections of the TESC tail system are gaining increasing interest. Because birds are easily observed on campus, often from trails, wildlife information kiosks should highlight birds using different components of the habitat, especially those that are critical to reproduction or survival (Zack 2002). For conservation efforts, kiosks should emphasize the causes of declining bird populations and the current research projects underway to reverse them. Integrating the public into the benefits of the TESC forest will encourage its respect and appreciation and generate support for academic work conducted there. The general public that utilizes trails and accesses the TESC forest may be interested in learning of the work going on there.

Participation in college sponsored events is an effective way to advertise the college and promote issues in conservation. The college already hosts many community events that draw large public crowds including the annual Science Fair and Super Saturday. International Migratory Bird Day or a Puget Sound bird festival would offer unique opportunities for the public and students to learn about bird conservation and TESC academic programs and research. Such events may also attract potential funders, collaborators and existing bird organizations, potentially increasing the visibility of EEON and EAMP. For scientists who wish to interact with the public, an emphasis on education and outreach as a part of the Evergreen science curriculum is extremely valuable. Teaching students how to effectively communicate with others outside a specific discipline is a necessary skill to take out into the world upon graduation.

3.73 Field based classes and university collaboration

Our college is unique in its widespread use of field based classes in many disciplines. In many cases getting to the field is as easy as stepping out the backdoor into the forest. The proximity of the forest to campus sets Evergreen apart from nearly every other college in the country (Hall et al. 1976). Field based classes and projects located on campus eliminate the costs of transportation, lodging, and administrative resources. The establishment of EEON emerged from the idea that faculty could facilitate ongoing student work directly on campus. Educating faculty about EEON and its potential academic opportunities will then allow faculty to engage students in additional field based curriculum right outside their door. Those that engage in projects linking field data collection and lab analysis will save time and resources with their field site located at their institution. As knowledge of EEON grows, students in varying disciplines may be interested in previously unexplored aspects of the forest. Students from other colleges around the Puget Sound often travel great distances to study the ecology or other scientific aspects of temperate rainforests. Students at University of Washington and University of Puget Sound travel to sites such as Wind River and H.J. Andrews Experimental Forests, hundreds of miles away from their institutions (HJ Andrews Experimental Forest 2002, Pacific Northwest Research Station 2007). Although these forests offer many attributes TESC cannot, our campus forest provides a viable additional field location and a much closer alternative for many student projects.

3.74 Banding workshops and community classes

The establishment of a banding program as part of EAMP is well underway and students enrolled in undergraduate programs, individual learning contracts and four credit electives have already learned about the operation of banding stations and obtaining data from live birds (i.e. Ornithology, Spring 2007, Avian Monitoring and Research Methods, Spring 2008, Avian Natural History, Summer 2008). Outside of academia, banding workshops are an increasingly popular means of educating the public about bird conservation while simultaneously training volunteers to become skilled in bird banding (Ralph et al. 2005, DeSante et al. 2008). TESC currently offers community and evening weekend special student classes. Banding workshops and classes could be effectively offered in this context along with banding components in more traditional TESC programs. Such workshops and classes could be offered either directly through the college or facilitated under the direction of a local non-profit such as BHAS or PSBO.

3.75 The Puget Sound Bird Observatory

Within the past few months a new regional non-profit as been created filling an important gap in avian conservation efforts throughout the Puget Sound basin. Newly created, the Puget Sound Bird Observatory (PSBO) has begun to establish objectives for the future and help fund several current projects (Puget Sound Bird Observatory 2008). The potential for collaboration between EAMP and PSBO in regards to education and community outreach is compelling. PSBO provides the opportunity to bring more expertise in field ornithology to campus projects and offer internships at other sites, and Evergreen may provide PSBO with additional membership and funding support through the academic sector. PSBO has begun its activities by hosting several banding workshops and MAPS sites around the Tacoma area. EAMP's own banding efforts may be enhanced through collaborative efforts with PSBO in terms of equipment, volunteers and project analysis.

3.8 Conclusions

The Evergreen Avian Monitoring Program is designed to assist in achieving scientific understandings and remedies for the alarming declines of many avian species and provide students with a venue for studies in Ornithology. The program will fill a regional gap with the collection of long-term avian data in a lowland temperate rainforest, and will bring together many different types of monitoring projects to answer a wider array of ornithological questions. The field site of the program is unique because it is physically located at a major public institution which offers the advantage of a variety of expertise and resources centrally located, as well as better use of academic research funds. These protocols on point counting, nest searching and bird banding can be used to develop field manuals for the various projects, evoke discussion about moving various projects forward, and inspire students and faculty to carry out ornithological research at the college. Such actions will help EAMP achieve its objective of becoming a long-term monitoring program grounded in TESC tradition and shared with the greater scientific community.

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Tables

Table 1. Confirmed breeding species. Astricks indicate possible focal species to be included in color banding and nest searching activities

Latin Name	Common Name
Haliaeetus leucocephalus	Bald Eagle
Accipiter cooperii	Cooper's Hawk
Patagioenas fasciata	Band-tailed Pigeon
Selasphorus rufus	Rufous Hummingbird
Sphyrapicus ruber	Red-breasted Sapsucker
Picoides pubescens	Downy Woodpecker
Picoides villosus	Hairy Woodpecker
Dryocopus pileatus	Pileated Woodpecker
Empidonax difficilis	Pacific-slope Flycatcher
Vireo gilvus	Warbling Vireo
Cyanocitta stelleri	Steller's Jay
Corvus corax	Common Raven
Poecile atricapillus	Black-capped Chickadee
Poecile rufescens	Chestnut-backed Chickadee
Sitta canadensis	Red-breasted Nuthatch
Certhia americana	Brown Creeper
Troglodytes troglodytes	*Winter Wren
Catharus ustulatus	*Swainson's Thrush
Turdus migratorius	*American Robin
Dendroica nigrescens	Black-throated Gray Warbler
Wilsonia pusilla	*Wilson's Warbler
Piranga ludoviciana	Western Tanager
Pipilo maculatus	*Spotted Towhee
Melospiza melodia	*Song Sparrow
Junco hyemalis	*Dark-eyed Junco
Carpodacus purpureus	Purple Finch
Carduelis pinus	Pine Siskin

Figures

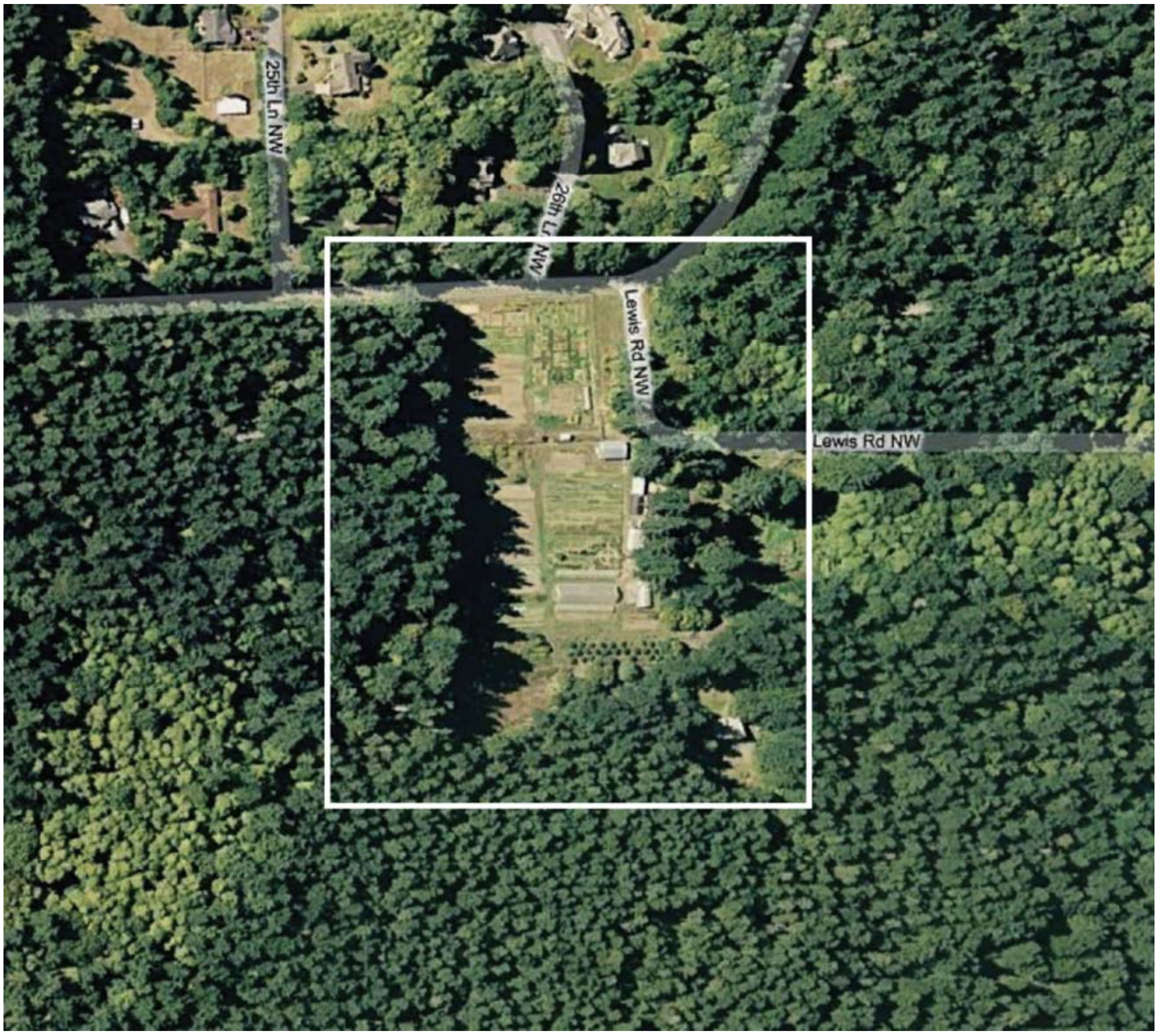


Figure 1a. Arial photograph of the Evergreen State College's organic farm showing surrounding forested lands (Google Earth image, 2008). Inset area of the farm's banding site shown below.

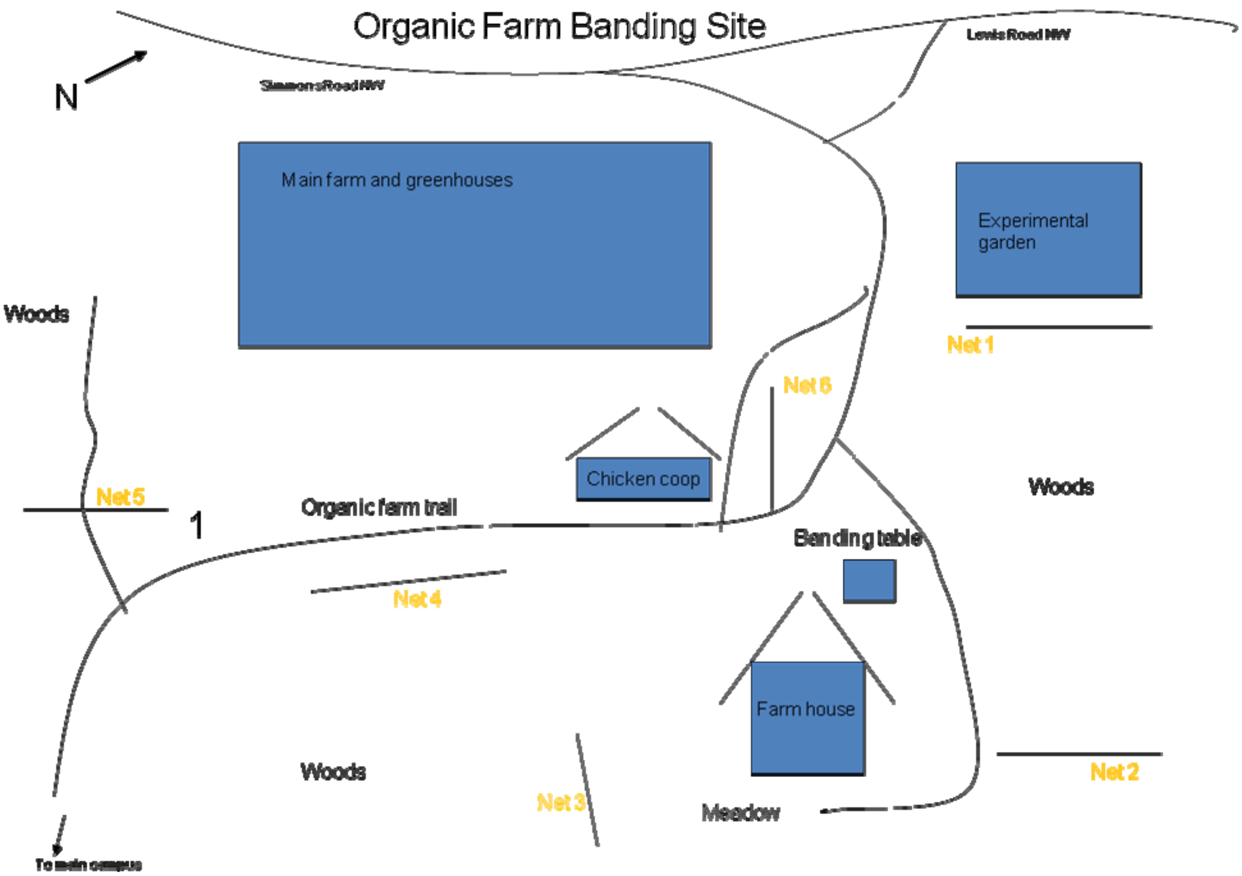


Figure 1b. Evergreen State College's organic farm banding site with experimental net locations.

Appendix A. Avian species detected during the 2008 breeding season in the Evergreen State College forest reserve, Olympia, WA. Asterisks indicate species documented but not detected during point counts. Shorebird and waterbird species are omitted.

Latin Name	Common Name	Acronym
Haliaeetus leucocephalus	Bald Eagle	BAEA
Accipiter cooperii	Cooper's Hawk	COHA
Buteo jamaicensis	Red-tailed Hawk	RTHA
Patagioenas fasciata	Band-tailed Pigeon	BTPI
*Bubo virginianus**	Great Horned Owl	GHOW
*Strix varia**	Barred Owl	BARO
Selasphorus rufus	Rufous Hummingbird	RUHU
Megaceryle alcyon	Belted Kingfisher	BEKI
Sphyrapicus ruber	Red-breasted Sapsucker	RBSA
Picoides pubescens	Downy Woodpecker	DOWO
Picoides villosus	Hairy Woodpecker	HAWO
Colaptes auratus	Northern Flicker	NOFL
Dryocopus pileatus	Pileated Woodpecker	PIWO
Contopus sordidulus	Western Wood-Pewee	WEWP
Empidonax hammondii	Hammond's Flycatcher	HAFL
Empidonax difficilis	Pacific-slope Flycatcher	PSFL
Vireo cassinii	Cassin's Vireo	CAVI
Vireo huttoni	Hutton's Vireo	HUVI
Vireo gilvus	Warbling Vireo	WAVI
Cyanocitta stelleri	Steller's Jay	STJA
Corvus brachyrhynchos	American Crow	AMCR
Corvus corax	Common Raven	CORA
Tachycineta bicolor	Tree Swallow	TRSW
Tachycineta thalassina*	Violet-green Swallow	VGSW
*Petrochelidon pyrrhonota**	Cliff Swallow	CLSW
*Stelgidopteryx serripennis**	Northern Rough-winged Swallow	NRWS
*Hirundo rustica**	Barn Swallow	BARS
Poecile atricapillus	Black-capped Chickadee	BCCH
Poecile rufescens	Chestnut-backed Chickadee	CBCH
Psaltriparus minimus	Bushtit	BUSH
Sitta canadensis	Red-breasted Nuthatch	RBNU
Certhia americana	Brown Creeper	BRCR
Thryomanes bewickii	Bewick's Wren	BEWR
Troglodytes troglodytes	Winter Wren	WIWR
Regulus satrapa	Golden-crowned Kinglet	GCKI
Regulus calendula	Ruby-crowned Kinglet	RCKI
Catharus ustulatus	Swainson's Thrush	SWTH
Catharus guttatus	Hermit Thrush	HETH
Turdus migratorius	American Robin	AMRO
Bombycilla cedrorum	Cedar Waxwing	CEDW

Vermivora celata	Orange-crowned Warbler	OCWA
Dendroica petechia	Yellow Warbler	YWAR
Dendroica coronata	Yellow-rumped Warbler	YRWA
Dendroica nigrescens	Black-throated Gray Warbler	BTYW
Dendroica townsendi	Townsend's Warbler	TOWA
Wilsonia pusilla	Wilson's Warbler	WIWA
Piranga ludoviciana	Western Tanager	WETA
Pipilo maculatus	Spotted Towhee	SPTO
Melospiza melodia	Song Sparrow	SOSP
Zonotrichia leucophrys	White-crowned Sparrow	WCSP
Junco hyemalis	Oregon Junco	ORJU
Pheucticus melanocephalus	Black-headed Grosbeak	BHGR
Agelaius phoeniceus	Red-winged Blackbird	RWBL
Molothrus ater	Brown-headed Cowbird	BHCO
Carpodacus purpureus	Purple Finch	PUFI
Carpodacus mexicanus	House Finch	HOFI
Loxia curvirostra	Red Crossbill	RECR
Carduelis pinus	Pine Siskin	PISI
Carduelis tristis	American Goldfinch	AMGO
Coccothraustes vespertinus	Evening Grosbeak	EVGR

Appendix B. List of trees, shrubs and herbaceous plants found in the Evergreen State College forest reserve, Olympia, WA sampled in EEON permanent plots, during the summer of 2008. Asterisks indicate a prominent species of the forest but not found during sampling

Scientific name	Common Name	Acronym
TREES		
Abies grandis	Grand Fir	ABGR
Acer macrophyllum	Big leaf maple	ACMA
Alnus rubra	Red alder	ALRU
Corylus cornuta	Beaked hazlenut	COCO
Cornus nuttallii	Pacific Dogwood	CONU4
Ilex aquifolium	English holly	ILAQ80
Picea sitchensis	Sitka Spruce	PISI
Pseudotsuga menziesii	Douglas-fir	PSME
Rhamnus purshiana	Cascara	RHPU
Salix scouleriana	Scouler's willow	SASC
Thuja plicata	Western redcedar	THPL
Tsuga heterophylla	Western hemlock	TSHE
*Populus balsamifera trichocarpa**	Black Cottonwood	POBAT
SHRUBS		
Gaultheria shallon	Salal	GASH
Mahonia nervosa	Dull Oregon-grape	MANE
Malus fusca	Oregon crabapple	MAFU
Holodiscus discolor	Oceanspray	HODI
Lonicera involucrata	Black twinberry	LOIN
Oemleria cerasiformis	Indian plum	OECE
Oplopanax horridus	Devil's club	OPHO
Rosa gymnocarpa	Baldhip rose	ROGY
Rubus parviflorus	Thimbleberry	RUPA?
Rubus spectabilis	Salmonberry	RUSP?
Rubus ursinus trailing	Blackberry	RUUR?
Sambucus racemosa	Red elderberry	SARA
Symphoricarpos albus	Common snowberry	SYAL
Vaccinium ovatum	Evergreen huckleberry	VAOV
Vaccinium parvifolium	Red huckleberry	VAPA
HERBS		
Adiantum pedatum	Maidenhair fern	ADPE
Arabis furcata	Columbia Gorge rockcress	ARFU
Asarum caudatum	Wildginger	ASCA
Asplenium viride	Green Spleenwort	ASVI
Athyrium filix-femina	Lady fern	ATFI
Blechnum spicant	Deer fern	BLSP
Bromus vulgaris	Columbia brome	BRVU
Bromus sp.	Unknown grass	Bromus sp.
Carex deweyana	Dewey sedge	CADE

Circaea alpina	Small enchanter's nightshade	CIAL
Claytonia sibirica	Siberian miner's lettuce	CLSI
Corallorhiza sp.	Pacific Coralroot	COME
Dactylis glomerata	Orchard grass	DAGL
Dicentra formosa	Pacific bleeding heart	DIFO
Dryopteris expansa	Spiny woodfern	DREX
Epilibium angustafolium	Fireweed	EPAN2
Epilobium ciliatum	Fringed willowherb	EPCI
Galium aparine	Cleavers	GAAP
Galium triflorum	Fragrant bedstraw	GATR
Galium trifidum	Small bedstraw	GATR2
Hedera helix	English ivy	HEHE
Hydrophyllum tenuipes	Pacific waterleaf	HYTE
Lactuca muralis	Wall lettuce	LAMU
Linnaea borealis	Twinflower	LIBO3
Lonicera ciliosa	Orange honeysuckle	LOCI
Melica subulata	Alaska oniongrass	MESU
Maianthemum dilatatum	False lily of the valley	MADI
Myosotis laxa	Small flowered forget-me-not	MYLA
Nemophila parviflora	Small flower nemophila	NEPA
Oenanthe sarmentosa	Pacific water-parsley	OESA
*Phalaris arundinace*a	Reed canary grass	PHAR
Polypodium glycyrrhiza	Licorice fern	POGL
Polystichum munitum	Sword fern	POMU
Pteridium aquilinum	Bracken fern	PTAQ
Rubus discolor	Himalayan blackberry	RUDI2
Stellaria crispa	Curled starwort	STCR
Tiarella trifoliata	Threeleaf foamflower	TITR
Tolmiea menziesii	Piggy-back plant	TOME
Trientalis latifolia	Broadleaf starflower	TRLA
Trillium ovatum	Trillium	TROV
Vancouveria hexandra	Inside-out flower	VAHE
Veronica americana	American brooklime	VEAM
Vicia sp.	Vetch	Vicia sp.
Viola palustris	Marsh violet	VIPA
Viola sempervirens	Evergreen violet	VISE

Appendix C. Blank datasheets for the point count, banding and nesting searching components of the Evergreen Avian Monitoring Program. Includes the following:
1) Point count field work checklist
2) Nest record cards
3) Nest record sheet
4) VCP form
5) Banding form
6) Net hours data sheet
7) Banding journal

Evergreen Avian Monitoring Program field work checklist

- ☐ Binoculars
- ☐ Rangefinders
- ☐ All weather field notebook
- ☐ Map of study area
- ☐ Multiple pencils
- ☐ Watch with timer showing seconds
- ☐ Flagging
- ☐ Point count data sheets
- ☐ Clipboard
- ☐ Nest record cards
- ☐ GPS

YEAR OBS
SPECIES DATE FOUND
NEST #

mo/day	time	min. at nest	RESULTS	CONTENTS B=building E=eggs Y=young	AGE OF YOUNG	BHCO CONTENTS (and age y)	CONSPIC before (1-4)	FLUSH (1-4)	DISTRESS after (1-4)

YEAR OBS
SPECIES DATE FOUND
NEST #

mo/day	time	min. at nest	RESULTS	CONTENTS B=building E=eggs Y=young	AGE OF YOUNG	BHCO CONTENTS (and age y)	CONSPIC before (1-4)	FLUSH (1-4)	DISTRESS after (1-4)

FINDING DATA (circle one)	MAP
RATE ABOVE: 0 1 2 3 4 RATE BELOW: 0 1 2 3 4 RATE APPROACH: 0 1 2 3 4 HUMAN PATH: 0 1 2 3 4 FIND DISTURBANCE: 0 1 2 3 4 FIND METHOD: F PB L SS NBC YB PY TIMESPENT: NUM PARENT VISITS: SEARCH RADIUS: NUM PREVIOUS TRY	
NEST SITE DESCRIPTION:	

FINDING DATA (circle one)	MAP
RATE ABOVE: 0 1 2 3 4 RATE BELOW: 0 1 2 3 4 RATE APPROACH: 0 1 2 3 4 HUMAN PATH: 0 1 2 3 4 FIND DISTURBANCE: 0 1 2 3 4 FIND METHOD: F PB L SS NBC YB PY TIMESPENT: NUM PARENT VISITS: SEARCH RADIUS: NUM PREVIOUS TRY	
NEST SITE DESCRIPTION:	

EAMP NEST RECORD SHEET

RESULTS (with description):____

____

FINDING DATA

Date [ ] (date found) Time [ ] (time found) Nestid [| | | | | | | | |] attempt Finder [ ]

Findcont [ ] Area [ ] Treatment [ ] locdist [ ] (distance in m from grid point) locdir [ ] locpt [ ]

rateabove [ ] ratebelow [ ] rateappr [ ] humanpath [ ] finddist [ ] (disturbance during finding)

findmeth [ ] timespent [ ] (minutes spent in finding) numparvis [ ] (# of parental visits during finding) searchrad [ ] m numprevtry [ ] (# previous attempts to find nest)

Male color combo [ ] Female color combo [ ]

NEST CHECKS

Date	Time	Min. @ nest	Nest cont seen	# Egg	# Yng.	CONSP	FLUSH	DISTR	Age Yng.	# CB Egg	# CB Yng.	Comments: Describe adult and nestling behavior, egg color and pattern, nestling development, predation events, nest condition, etc.

Closeout precision co	Cownumegg	Fledgenum:	**The following if exact**	Hatchdate:

EAMP Variable Circular Plot (VCP) Point Count Data Form

State | Forest Type | Plot | Month | Day | Year | Visit

First Name | Last Name | Address | Telephone | Email

Point #	Time	Species code	Dist. (m)	Estimated how? (R/WO/E)	Cue (V/S/C)	Cluster Size	Interval (1,2,3 min)	Behavioral Observations

Behav. Obs: AF = aerial foraging, CO = copulation, MC = material carry, FC = food carry, NF = nest found, FL = fledglings, FS = fecal sac carry, DD = distraction display, PA = pair, DI = display

Weather Information: Please estimate temperature, cloud cover (% of sky covered by clouds), and approximate wind speed.

______˚ F or C (circle one) ______% ______ mph, knots, or kmph (circle one) ______ (Y/N)

Temperature | Cloud Cover | Wind Speed | Raining

Canopy Cover (Y/N) | ENTERED | PROOFED

x

EEON Banding Sheet

Station ____________

Permit No. ____________

New	N
Recap	R
Unbanded	U
Destroyed	D
Changed	C
Lost	L

Start Date:

End Date:

Use "9" for Data Not Taken

Plum, Juv	J	Brood Patch	B	Feather Wear	F	PP Covert Shape	V
Plum, 1st Win.	H	Bill/Mouth	I	Molt	M	Primary Shape	P
Plum, Adult	A	Skull	S	Wing Chord	W	Rectrix Shape	R
Cloacal Pr.	C	Eye	E	Other	X	Tail Length	T

U	0	AHY	3	TY	6
Local	1	SY	4	ATY	7
HY	2	ASY	5		

Male	M
Female	F
?	U

Band Numbers

From:

To:

300	Normal
301	Color Banded
615	Injured
000	Unbanded

Year ____________

Page ____________

Bander	Code	Band Number	Species Code	A.O.U.	Age	how	Sex	how	Skull	Br.P.	Cl.P	Fat	Body Molt	FF Molt	Wear	Fade	Wing Chord(mm)	Weight(grams)	Status	Date Day Month	Time	Lo

Banders:

State ☐☐ **Region** ☐☐☐☐☐☐☐☐ **Station** ☐☐☐☐ **Year** ☐☐☐☐ **Operator(s):** ____________________

	Net Location:																	Total Nets
	Number of Nets:																	
Mo./ Day	Open Time	Close Time	Hours Open	Number of Net-Hours Per Location														Total Net-Hours

"Closed Early" Codes: W = wind R = rain H = heat C = cold *O = other

gb10/94

EVERGREEN AVIAN MONITORING PROGRAM DAY: DATE:
BANDING JOURNAL

LOCATION: exported weather data ☐
initials ______

	WEATHER											
INI	TIME	WIND DIRECTION (True)	WIND FORCE (kmph)	VISIBILITY (km)	WEATHER (codes)	BAROMETER (inches)	TEMP (Celsius)	CLOUDS % COVER (tenths)	CLOUDS TYPE (code)	RAIN (mm) Current	RAIN (mm) Annual July-June

TEMPERATURE: HIGH: LOW:

PERSONNEL: NUMBER OF VISITORS:

WEATHER SUMMARY:

ACTIVITIES:

EVERGREEN AVIAN MONITORING PROGRAM DAY: DATE:

Nets Open: **Nets Closed:** **Total Net Hours:**

Explanations and Times for Closed Nets:

BANDING SUMMARY

UNBANDED SPECIES	NEW CAPTURES HY	AHY	SY	ASY	U	RECAPTURES HY	AHY	SY	ASY	U

SITE BIRD LIST (Seen, Heard or Banded)

Appendix D. Supplemental tables and figures

Priority bird species outlined by PIF that breed primarily in forests and were detected at least once during the 2008 survey.

Species[1]	BCR[2]	B_Tier[3]	N_Tier[3]	Estimated Population	Continental Objective[3]	Target population
Cooper's Hawk	5	II.a.		4,200	1	4,200
Cooper's Hawk	9			3,100	1	3,100
Cooper's Hawk	10			720	1	720
Band-tailed Pigeon	5	I.	I.	160,000	2	320,000
Band-tailed Pigeon	9	I.	I.	4,700	2	9,400
Red-breasted Sapsucker	5	II.a.	II.a.	31,000	1	31,000
Red-breasted Sapsucker	9			66,000	1	66,000
Hammond's Flycatcher	5			150,000	1	150,000
Hammond's Flycatcher	9			340,000	1	340,000
Hammond's Flycatcher	10	II.a.		270,000	1	270,000
Pacific-slope Flycatcher	5	II.a.		850,000	1	850,000
Pacific-slope Flycatcher	9			320,000	1	320,000
Pacific-slope Flycatcher	10			44,000	1	44,000
Cassin's Vireo	5	II.a.		13,000	1	13,000
Cassin's Vireo	9			100,000	1	100,000
Cassin's Vireo	10	II.b.		140,000	1	140,000
Hutton's Vireo	5	II.b.		71,000	1	71,000
Hutton's Vireo	9			810	1	810
Steller's Jay	5	II.a.		140,000	1	140,000
Steller's Jay	9			49,000	1	49,000
Steller's Jay	10			12,000	1	12,000
Northwestern Crow	5	II.a.	II.a.	5,000	1	5,000
Chestnut-backed Chickadee	5	II.a.	II.a.	650,000	1	650,000
Chestnut-backed Chickadee	9			170,000	1	170,000
Chestnut-backed Chickadee	10			8,900	1	8,900
Bushtit	5		II.a.	70,000	1.5	110,000
Bushtit	9			1,500	1.5	2,300
Golden-crowned Kinglet	5	II.a.		1,300,000	1	1,300,000
Golden-crowned Kinglet	9			550,000	1	550,000
Golden-crowned Kinglet	10			180,000	1	180,000
Varied Thrush	5	II.a.		430,000	1	430,000
Varied Thrush	9			330,000	1	330,000
Varied Thrush	10			9,800	1	9,800
Black-throated Gray Warbler	5	II.a.		250,000	1	250,000
Black-throated Gray Warbler	9	II.a.		160,000	1	160,000
Townsend's Warbler	5	II.a.	II.c.	210,000	1	210,000
Townsend's Warbler	9			410,000	1	410,000
Townsend's Warbler	10	II.b.		160,000	1	160,000
Purple Finch	5	II.a.		92,000	1.5	140,000
Purple Finch	9			27,000	1.5	41,000
Red Crossbill	5	II.a.		190,000	1	190,000
Red Crossbill	9			78,000	1	78,000
Red Crossbill	10			120,000	1	120,000

1 See appendix A for latin names
2 BCR=Bird Conservation Region, the southern pacific rainforests are region 5.
3 B_tier= breeding
N_tier=non-breeding/wintering
Tier I. *High Continental Importance.*-- Species on the *PIF Continental Watch List,* which are typically of conservation concern throughout their range. These are species showing high vulnerability in a number of factors. High level conservation attention warranted.
Tier II. *High Regional Priority.* Species that are of moderate continental priority (not on *Continental Watch List)* , but are important to consider for conservation within a region.
Tier IIA. *High Regional Concern.* Species that are experiencing declines in the core of their range and that require conservation action to reverse or stabilize trends. These are species with a combination of high area importance and declining (or unknown) population trend.
Tier IIB. *High Regional Responsibility.* Species for which this region shares in the responsibility for long-term conservation, even if they are not currently declining or threatened. These are species of moderate overall priority with a disproportionately high percentage of their total population in the region.
Tier IIC. *High Regional Threats.* Species of moderate overall priority that are uncommon in a region and whose remaining populations are threatened, usually because of extreme threats to sensitive habitats. These are species with high breeding threats scores within the region.
Continental objectives: 1=maintain 1.5-=increase/maintain 2=increase

Washington State Population Objectives outlined by Partners in Flight (Rosenberg 2004) for those species detected in 2008 surveys.

***Species*[1]**	***Statewide population objectives for forest species***
Cooper's Hawk	Maintain the current statewide population of 8,000 individuals.
Band-tailed Pigeon	Double the statewide population from 160,000 individuals to 320,000 individuals.
Red-breasted Sapsucker	Maintain the current statewide population of 97,000 individuals.
Hammond's Flycatcher	Maintain the current statewide population of 760,000 individuals.
Pacific-slope Flycatcher	Maintain the current statewide population of 1,200,000 individuals
Cassin’s Vireo	Maintain the current statewide population of 250,000 individuals.
Hutton's Vireo	Maintain the current statewide population of 72,000 individuals.
Steller's Jay	Maintain the current statewide population of 200,000 individuals.
Northwestern Crow	Maintain the current statewide population of 5,000 individuals.
Chestnut-backed Chickadee	Maintain the current statewide population of 830,000 individuals.
Bushtit	Increase the statewide population from 72,000 individuals to 110,000 individuals.
Golden-crowned Kinglet	Maintain the current statewide population of 2,000,000 individuals
Varied Thrush	Maintain the current statewide population of 770,000 individuals.
Black-throated Gray Warbler	Maintain the current statewide population of 410,000 individuals.
Townsend’s Warbler	Maintain the current statewide population of 780,000 individuals.
Purple Finch	Increase the statewide population from 120,000 individuals to 180,000 individuals
Red Crossbill	Maintain the current statewide population of 390,000 individuals.

1 See appendix A for latin names

Species richness and diversity indices[1] for EEON 2008 breeding bird survey

Plot	Sp. richness	Sp. evenness	Shannon's Index	Simpson's Index
A11	14	0.965	2.547	0.915
A7	15	0.936	2.534	0.910
B10	14	0.898	2.370	0.877
B11	16	0.928	2.572	0.907
B4	13	0.924	2.370	0.895
B5	14	0.923	2.435	0.899
B6	20	0.905	2.711	0.919
B7	16	0.933	2.586	0.913
B8	18	0.928	2.683	0.920
B9	17	0.902	2.557	0.899
C10	17	0.960	2.719	0.926
C11	17	0.932	2.640	0.917
C3	15	0.910	2.465	0.900
C4	16	0.925	2.563	0.907
C5	18	0.920	2.660	0.914
C6	17	0.914	2.590	0.905
C7	14	0.950	2.506	0.909
C8	17	0.938	2.658	0.920
C9	12	0.941	2.338	0.889
D1	16	0.939	2.604	0.915
D10	23	0.938	2.942	0.937
D11	15	0.936	2.535	0.907
D2	19	0.938	2.762	0.927
D3	21	0.915	2.787	0.926
D4	19	0.884	2.602	0.901
D5	16	0.932	2.585	0.913
D7	16	0.933	2.588	0.912
D8	16	0.924	2.561	0.908
D9	18	0.917	2.651	0.913
E1	15	0.942	2.551	0.909
E10	15	0.947	2.566	0.914
E11	22	0.957	2.958	0.942
E2	13	0.945	2.424	0.903
E3	16	0.912	2.528	0.907
E4	17	0.927	2.628	0.915
E8	18	0.944	2.727	0.926
E9	17	0.940	2.664	0.922
F3	16	0.933	2.588	0.911
G7	13	0.929	2.383	0.896
H6	14	0.948	2.501	0.910
H7	15	0.900	2.437	0.891
I6	19	0.917	2.700	0.921
I7	16	0.926	2.568	0.911
J5	17	0.924	2.617	0.913
J6	20	0.911	2.730	0.919
K6	16	0.918	2.545	0.904
K7	15	0.944	2.557	0.914
forest average	16.447	0.929	2.591	0.911

1 Community indices defined as follows: richness= total number of species detected per a plot; eveness= a measure of how well each species is represented in each plot; Shannon's Index= the Shannon-Weaver index of diversity (Shannon and Weaver 1949); Simpson's Index= represents the probability that two randomly selected individuals in within each plot belong to the same species (Simpson 1949).

Comparison of canopy cover between spring (March-May) and summer (June-August) showing how decidiuous trees influence canopy cover.

Plot	spring 2008	summer 2008	% decidiuous
B7	71%	86%	0
B8	72%	92%	4
B9	66%	93%	58
B10	54%	90%	46
B11	69%	92%	13
C8	68%	67%	1
C9	82%	82%	0
C10	68%	87%	50
C11	63%	82%	1
E11	87%	81%	1
D9	83%	76%	69
D10	82%	68%	100
A11	74%	89%	58
D11	86%	87%	13
E8	85%	89%	44
E9	86%	78%	43
E10	80%	82%	50
A7	62%	87%	100
C7	71%	71%	0
D7	85%	75%	61
D8	88%	86%	60
C4	73%	86%	0
C5	71%	92%	80
D4	86%	86%	100
C3	76%	91%	30
C6	68%	87%	25
D1	89%	74%	11
D2	84%	90%	13
D3	84%	92%	72
D5	80%	88%	44
E1	75%	93%	10
E2	85%	92%	28
E3	83%	88%	79
E4	89%	87%	27
F3	79%	84%	44
G7	87%	73%	21
H6	90%	71%	31
H7	90%	80%	14
I6	87%	75%	92
I7	91%	76%	0
J6	89%	92%	33
B4	64%	88%	50
B5	69%	79%	47
B6	75%	86%	59
average	**78%**	**84%**	**38**
StDev	**9%**	**7%**	**31**
SE	**1%**	**1%**	**5**

Forest floor associated bird species dectected during 2008 surveys at the Evergreen State College forest reserve. Forest floor associated birds are defined here as those species which breed near or on the ground and forage there.

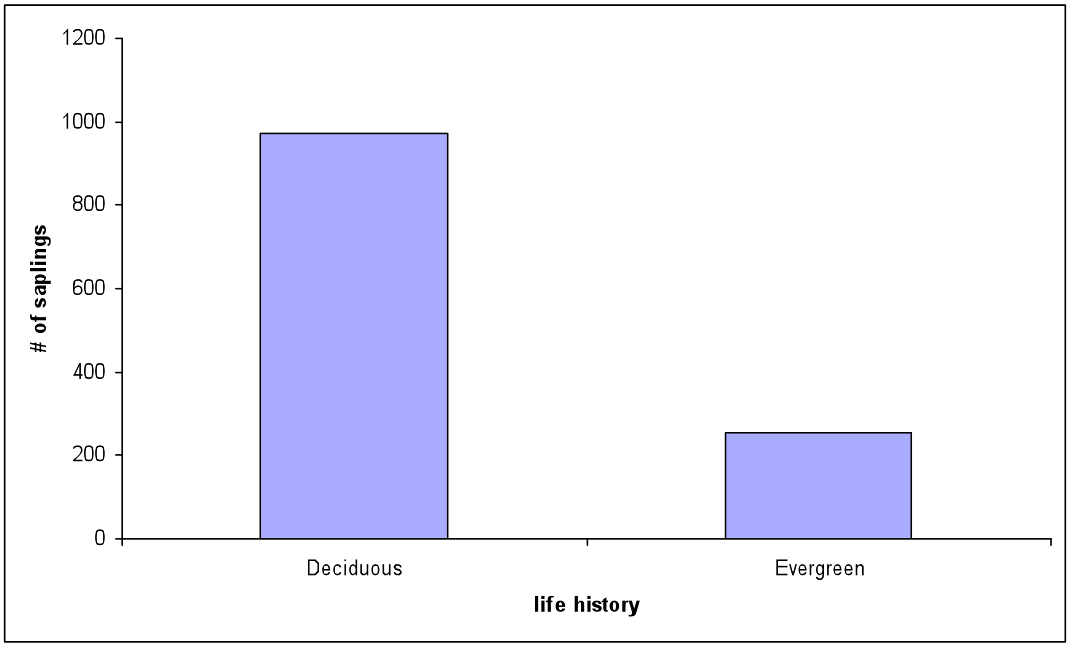
Latin name	Common name	Number of detections
Troglodytes troglodytes	Winter wren	218
Catharus ustulatus	Swainson's thrush	131
Turdus migratorius	American robin	218
Pipilo maculatus	Spotted Towhee	115
Melospiza melodia	Song Sparrow	172
Junco hyemalis	Oregon Junco	35

Snag dependent bird species, defined by their nesting or foraging ecology, found during 2008 surveys in the The Evergreen State College forest reserve.

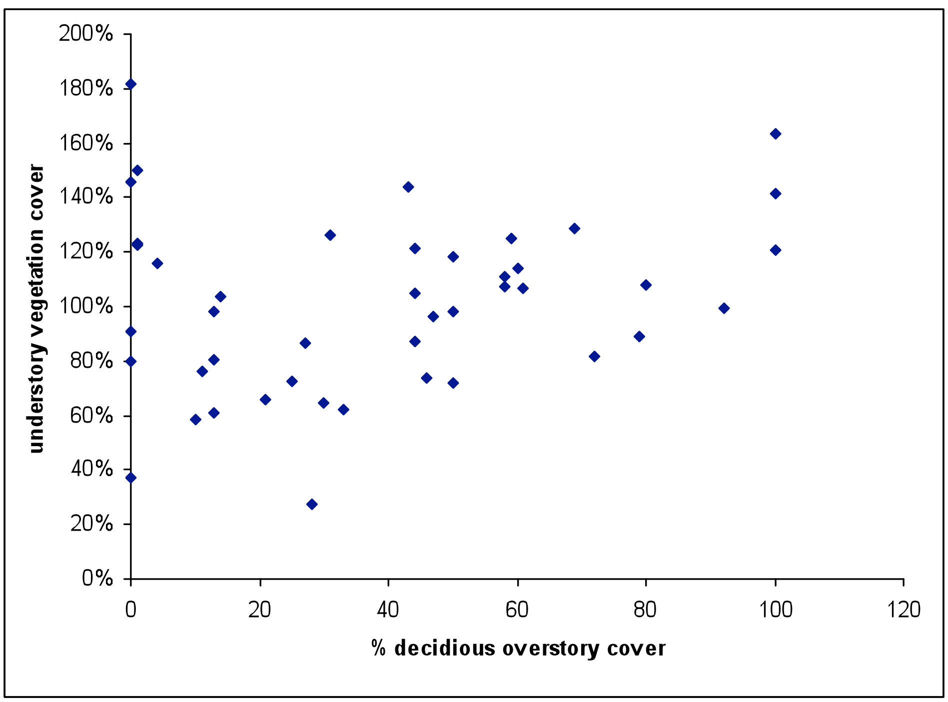
Latin name	Common name	Primary cavity nester	Secondary cavity nester
Sphyrapicus ruber	Red-breasted Sapsucker	X	
Picoides pubescens	Downy Woodpecker	X	
Picoides villosus	Hairy Woodpecker	X	
Colaptes auratus	Northern Flicker	X	
Dryocopus pileatus	Pileated Woodpecker	X	
Tachycineta bicolor	Tree Swallow		X
Tachycineta thalassina	Violet-green Swallow		X
Poecile atricapillus	Black-capped Chickadee	X	
Poecile ruf escens	Chestnut-backed Chickadee	X	
Sitta canadensis	Red-breasted Nuthatch	X	
Certhia americana	Brown Creeper		X
Thryomanes bewickii	Bewick's Wren		X
Troglodytes troglodytes	Winter Wren		X

The total number of snags found in EEON permanent plots with average DBH (cm), height (m), and decay stage (1-9). Decay diversity and snag biomass (kg) are also shown.

Plot	Snag #	Mean DBH	Mean height	average decay stage	decay stage diversity	snag biomass
A11	4	45.39	29.72	3	4	829.04
A7	5	92.28	0.91	8	4	173.08
B10	3	97.03	2.44	7	4	455.04
B11	5	127.97	0.70	9	4	324.33
B4	11	33.73	7.01	6	8	854.74
B5	16	30.73	11.89	6	5	1198.83
B6	3	33.10	10.97	6	3	524.23
B7	24	17.60	5.79	6	7	579.29
B8	6	60.86	0.91	7	3	154.28
B9	6	44.68	2.44	8	2	109.03
C10	9	144.78	0.61	9	4	131.44
C11	5	22.91	13.72	5	4	866.20
C3	1	7.19	4.57	3	1	2.40
C4	12	14.81	8.53	7	5	229.28
C5	4	31.27	0.91	8	3	27.60
C6	1	28.83	1.83	4	1	16.53
C7	4	22.50	19.20	3	1	1373.43
C8	20	26.64	14.33	5	8	4182.62
C9	15	23.52	14.94	5	7	1945.53
D1	2	19.20	1.83	7	2	6.10
D10	3	20.83	4.66	6	3	45.43
D11	8	51.46	5.97	7	5	375.62
D2	5	63.09	1.22	9	4	585.28
D3	4	13.77	3.96	8	2	35.40
D4	5	15.85	8.84	6	4	134.88
D5	5	61.11	3.05	6	3	332.41
D7	6	8.26	3.35	2	3	16.19
D8	9	97.54	0.91	9	3	602.41
D9	3	12.70	3.05	7	2	38.13
E1	7	34.87	0.61	8	3	37.49
E10	4	21.08	22.86	2	4	207.38
E11	5	33.68	10.36	7	4	575.00
E2	13	46.84	2.44	6	7	460.68
E3	4	89.13	0.61	8	2	68.43
E4	10	70.76	1.22	8	4	476.53
E8	8	27.71	6.10	4	4	113.00
E9	6	8.38	3.66	5	4	278.85
F3	11	26.67	1.83	8	4	46.70
G7	7	35.56	0.61	9	4	46.12
H6	17	29.57	0.91	8	3	158.95
H7	3	49.20	0.91	8	2	29.61
I6	7	62.23	3.05	6	3	639.80
I7	1	18.92	1.52	8	1	2.94
J6	1	78.00	1.52	5	1	87.39
TESC Forest Average	7	43.23	5.60	6	4	440.00



Sapling counts in 44 EEON plots exemplifying the role of the deciduous community to overall forest structure via recruitment.



Correlation between percent deciduous canopy cover and understory vegetation cover in EEON permanent plots.