Breeding bird populations in logged and unlogged forest stands in southwestern Montana
by Kathleen Elizabeth Mulqueen

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
Forest fragmentation and changing population dynamics of breeding bird communities have recently received a great deal of attention in the ecological literature. Temperate montane forests of western North America, landscapes once relatively unused by humans, have recently been subject to profound increases in human population use, development, and resource extraction pressures. The resulting landscape fragmentation has led to both a quantitative and qualitative loss of habitat for many neotropical migrants and forest interior specialists. Although numerous studies have documented the effects of forest fragmentation on populations of forest songbirds in the eastern deciduous forest biome of North America, few have focused on coniferous forests of the central and northern Rocky Mountains. It is within these landscapes that resource use and extraction (i.e., timber harvesting) are changing and fragmenting the landscape. The purpose of this study was to compare bird species abundance and richness in forest stands affected by different types of logging in an area located within the Gallatin National Forest, south of Bozeman, Montana. Breeding bird surveys were conducted during the 1991 and 1992 breeding seasons, and vegetation characteristics were measured in each stand type. Stand types included a clear-cut, partial-cut, adjacent old-growth forest, and associated edge habitats. Avian populations were shown to be appreciably affected by changes in vegetation structure due to silvicultural practices. Average bird abundance and richness were significantly higher in the partial-cut than in either the clear-cut or old-growth, and significantly lower in the clear-cut than in any other stand type. There was no significant difference in average bird abundance or species richness between either edge type. Bird species composition varied among the different stand types, with the clear-cut attracting bird species that prefer open areas such as ground foragers and ground nesters, and the old-growth supporting higher numbers of bark gleaners and cavity nesters. The partial-cut provided some elements for both open and closed forest avian species. The study of birds and changes in their abundance and distribution due to timber harvesting activities can provide important information useful in designing strategies that allow management of forest resources in concert with conservation of avian communities.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Forest fragmentation and changing population dynamics of breeding bird communities have recently received a great deal of attention in the ecological literature. Temperate montane forests of western North America, landscapes once relatively unused by humans, have recently been subject to profound increases in human population use, development, and resource extraction pressures. The resulting landscape fragmentation has led to both a quantitative and qualitative loss of habitat for many neotropical migrants and forest interior specialists. Although numerous studies have documented the effects of forest fragmentation on populations of forest songbirds in the eastern deciduous forest biome of North America, few have focused on coniferous forests of the central and northern Rocky Mountains. It is within these landscapes that resource use and extraction (i.e., timber harvesting) are changing and fragmenting the landscape. The purpose of this study was to compare bird species abundance and richness in forest stands affected by different types of logging in an area located within the Gallatin National Forest, south of Bozeman, Montana. Breeding bird surveys were conducted during the 1991 and 1992 breeding seasons, and vegetation characteristics were measured in each stand type. Stand types included a clear-cut, partial-cut, adjacent old-growth forest, and associated edge habitats. Avian populations were shown to be appreciably affected by changes in vegetation structure due to silvicultural practices. Average bird abundance and richness were significantly higher in the partial-cut than in either the clear-cut or old-growth, and significantly lower in the clear-cut than in any other stand type. There was no significant difference in average bird abundance or species richness between either edge type. Bird species composition varied among the different stand types, with the clear-cut attracting bird species that prefer open areas such as ground foragers and ground nesters, and the old-growth supporting higher numbers of bark gleaners and cavity nesters. The partial-cut provided some elements for both open and closed forest avian species. The study of birds and changes in their abundance and distribution due to timber harvesting activities can provide important information useful in designing strategies that allow management of forest resources in concert with conservation of avian communities.

CHAPTER 1

INTRODUCTION

Forest fragmentation and changing population dynamics of long-distance migratory passerine species have recently received a great deal of attention in the ecological literature (Aldrich and Robbins 1970; Robbins 1979; Ambuel and Temple 1982, 1983; Lynch and Whigham 1984; Blake and Karr 1987; Lynch 1987). Growing scientific consensus confirms that the decline of breeding bird populations is real, abnormal, and of international concern (Noon and Young 1991). Studies (Whitcomb et al. 1981; Wilcove 1985) have shown that both neotropical migrants and forest interior specialists are particularly affected by destruction and fragmentation of forests in both the breeding ranges of North America and their tropical wintering grounds.

Temperate montane forests of western North America, landscapes once relatively unused by humans, have recently been subject to profound increases in population use, development, and resource extraction pressures. The resulting landscape fragmentation, in which relatively large forest tracts have been broken into a mosaic of smaller, dissimilar habitat patches has led to an increased proportion of forest-edge habitat and a disruption of spatial continuity. Although there have been numerous studies documenting the effects of forest fragmentation on populations of forest songbirds in the eastern deciduous forest biome of North America, there have been relatively few studies which have documented the population dynamics of birds in the central and northern Rocky Mountains. It is within these landscapes that

resource use and extraction (i.e., various forms of timber harvesting) are altering and fragmenting the landscape. With the need for a consensus between sustainable development and conservation in mountain environments, an understanding of bird population changes in association with forest fragmentation is needed.

Study Objectives

The purpose of this study was to compare bird species richness and abundance in forest stands affected by different types of logging in a landscape of southwestern Montana that has a long history of resource use and extraction. Because organisms are inherently susceptible to variations in climate and other environmental conditions on a year to year basis, a repeated bird survey was necessary to strengthen the credibility of the final results. Strong, credible data will be useful to resource management agencies. Specifically, the three objectives were to: (1) determine differences in total bird abundance and bird richness observed within different forest stands (i.e., clear-cut, partial-cut, old growth forest, and edge habitats) and years, (2) determine differences in nesting and foraging guild assemblages within the different stands, and (3) characterize the vegetation within the different stands and relate these characteristics to bird abundance and richness.

Significance of Study

Ecological components are inseparably linked to the patterns of landscape, both in space and time. The changing abundance and diversity of

plants and animals over a range of temporal and spatial scales is fundamental to biogeography (Veblen 1987). Anthropogenic landscape modification has played a significant role in changing the structure and composition of habitat communities with ensuing changes in wildlife distribution. For example, the spatial distribution of resources within an ecosystem controls the availability, utilization, and interchange of resources among organisms living in the community. Changes in the geographical character (i.e., landscape fragmentation over time) within a particular area will have direct and indirect implications to the organisms inhabiting both the local area and region as a whole. For example, a large, undisturbed continuous forest may provide an important pool of resources for maintenance and continued colonization of species on a regional scale or it may provide critical refuges for migrant species on a wider geographical scale.

Changes in vegetation structure can make a habitat less acceptable or even unacceptable for one species, while at the same time making it more acceptable to another species. Such changes do occur naturally, but the incidence of these changes and the severity of their effects on bird communities have been greatly accelerated due to human influences. As humans have changed the environment, some species of birds have become more abundant, some have decreased in numbers, and others have become extinct. Maintaining biodiversity in forests leads to an important question of land use practices and their consequent effects on wildlife. The study of changes in bird abundance and distribution due to both intentional management (i.e., timber harvesting) and inadvertent impacts (i.e., increased number of logging roads and therefore, increased post-harvest human access to formerly inaccessible, pristine areas) can lead to useful information in the

context of managing for both conservation and resource utilization and development.

The challenge to achieve conservation and sustainable development will depend on solid and specific information on human/biota interactions. Results of this study may have important applications to avian habitat preservation in old-growth forest patches and wildlife habitat management techniques involving timber harvesting activities. Results will also provide documented baseline data of breeding bird populations in several habitat types in the Hyalite drainage of southwestern Montana. This information can be useful for incorporating potential mitigating factors (such as retention of snags or revegetation projects) into future timber management plans. Changes in the way in which timber is harvested may be needed if a representative and viable bird population is to continue to exist in this region.

Previous Studies

Forest fragmentation is the process by which large, continuous forest tracts are reduced to numerous smaller tracts isolated from one another either by development of some kind or by an area unlike the original forest (McLellan et al. 1986). Through time the ecosystem is broken into a mosaic of smaller, dissimilar habitat patches (Figure 1) resulting in a disruption of spatial continuity at varying degrees of scale (Lord and Norton 1990). Forest fragmentation has several components including: (1) reduction in total habitat area reducing the amount of resources available for species dependant upon mature forest habitat, (2) redistribution of the remaining area into

disjunct fragments that may become isolated from one another (insularization), negatively influencing immigration and colonization rates, and (3) an increased proportion of edge habitat at the expense of interior habitat. Within wildlife communities some species (i.e., specialists) are more habitat specific than others (i.e., generalists) and thus exhibit different degrees of tolerance to fragmentation. For forest-interior bird species living in ecosystems containing large continuous tracts of habitat with relatively few edges, the anthropogenic process of habitat fragmentation results not only in a quantitative reduction of habitat area, but also a qualitative alteration of habitat area (Temple and Wilcox 1986).

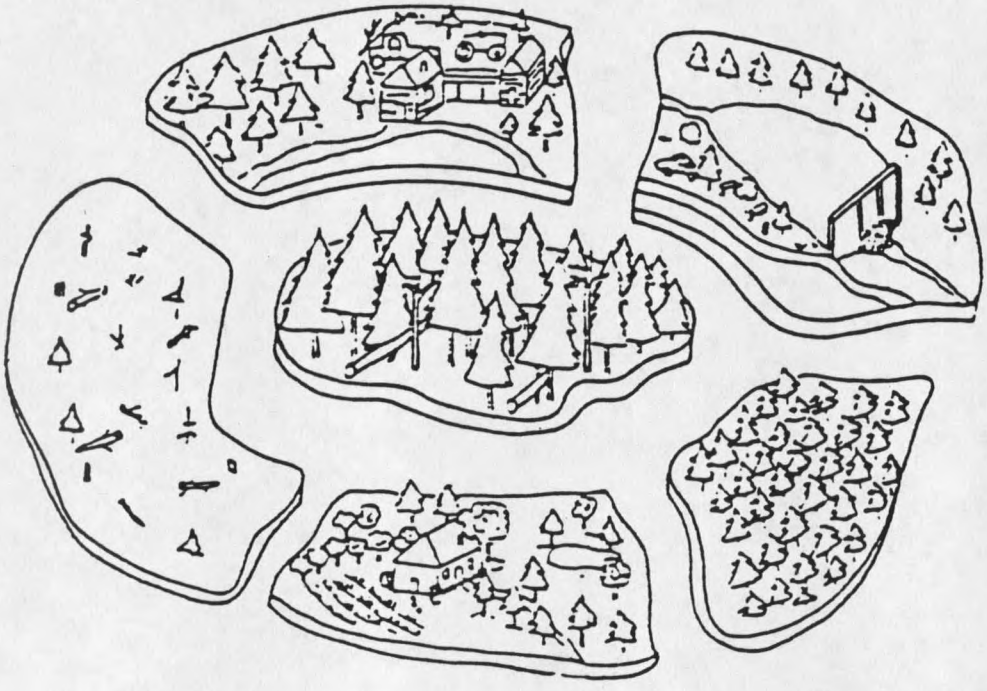

Figure 1. Insularization of old-growth ecosystem patches results from numerous forms of forest management and development (from Harris 1984).

The effects of habitat fragmentation with respect to interior forest-dwelling songbirds are numerous. These include insularization effects (Robbins 1979, 1980; Whitcomb et al. 1981; Lynch and Whigham 1984), competitive replacement by other species due to changes in habitat structure (Ambuel and Temple 1983), an increase in cowbird parasitism (Mayfield 1965, 1977; Whitcomb et al. 1981; Brittingham and Temple 1983; Post et al. 1990), and an increase in nest predation by squirrels, cats, jays, and other predators (Gates and Gysel 1978; Ambuel and Temple 1983; Wilcove 1985; Burger 1988). The increased area of forest-edge ecotone provides easy access to the forest for species which are predominantly non-forest species. In addition, these edge habitats may function as biological barriers that serve as predator travel lanes (Bider 1968; Ratti and Reese 1988).

Information indicating the decline or disappearance of migratory bird populations in the eastern United States has been accumulating since the 1950's (Aldrich and Robbins 1970; Robbins 1979; Ambuel and Temple 1982; Wilcove and Whitcomb 1983; Lynch 1987). The most common species reported as scarce in or missing from areas where they were formerly abundant are small passerine birds. Since the early settlement of the United States by Europeans from 375 to 100 years ago, human-induced changes in North American songbird habitats have been profound (Aldrich and Robbins 1970). Although many eastern states have had considerable forest regrowth due to farmland reversion and fire suppression practices since the 1930's (Williams 1989), the present landscape in eastern North America, when compared to the once extensive forest tracts of the region before the settlement of Europeans, provides a good example of fragmentation on a temporal scale (Figure 2). It can be seen that as the average patch size decreases, the proportionate amount of edge increases (i.e., the interior:edge

ratio decreases). More than 300 million acres of forest land were cleared by the beginning of the 20th century due to increased population expansion, industrialization, agriculture, and changing land use patterns (Williams 1989). Forest patches (or "islands") embedded in a matrix of non-forest landscape, exist as remnants of the deciduous forest biome of pre-settlement time.

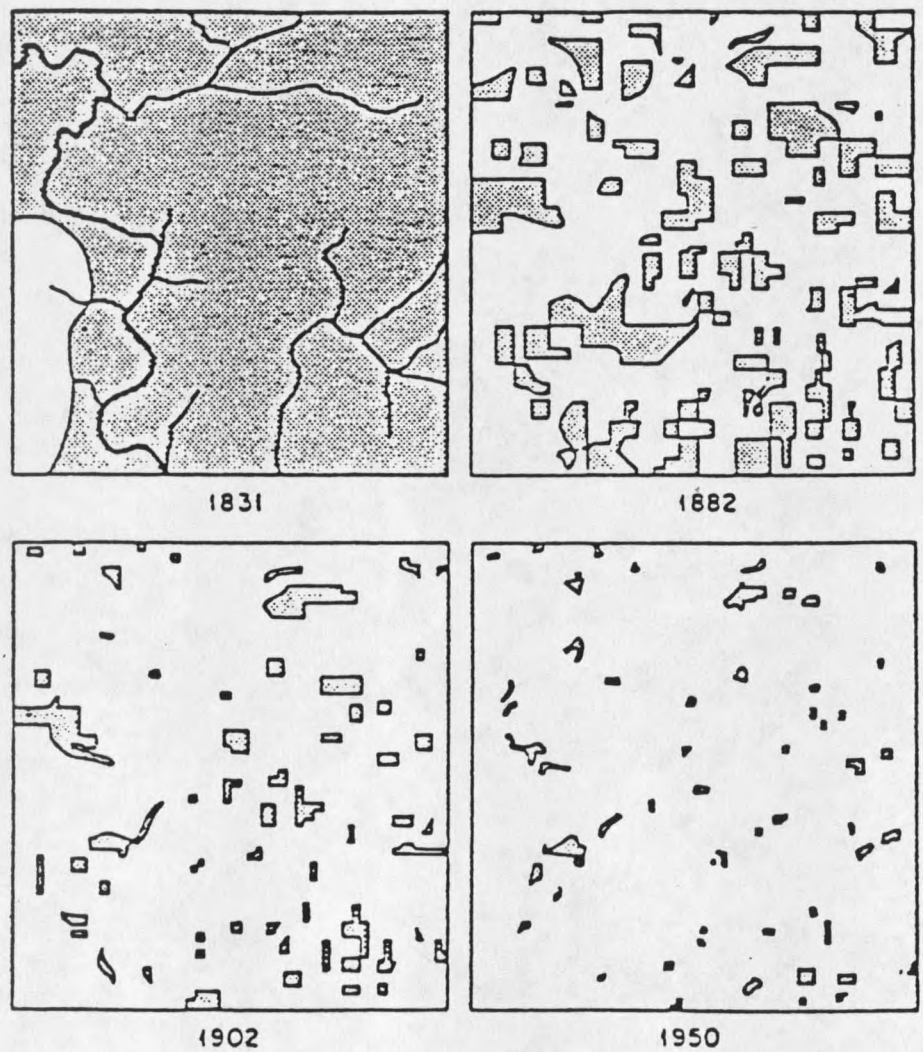

Figure 2. Changes in wooded area of Cadiz Township, Green County, Wisconsin, during the period of European settlement. The shaded areas represent the land remaining in, or reverting to, forest in 1882, 1902, and 1950 (from Burgess and Sharpe 1981).

On an evolutionary scale, however, this occurrence in North America is a relatively recent phenomenon. In Great Britain, for example, reduction and fragmentation of the original forest cover began at least 5000 years ago during the Neolithic period (Darby 1972). By the time of the Norman Conquest (1066 A.D), clearance of the natural woodlands was well advanced. In Great Britain today, pressure on the land continues to be so great that many of the "semi-natural" habitats which replaced the original forest are themselves severely reduced and fragmented (Wilcove et al. 1986).

In the United States, forests are continually fragmented as a result of timber harvesting and development. Human alteration of habitats, such as old-growth Douglas fir forests on the west coast (Harris 1984; Rosenberg and Raphael 1986), mature mixed-conifer forests in the Rocky Mountain region (Ratti and Reese 1988; Hejl and Woods 1990), and deciduous forests in the east (Burgess and Sharpe 1981; Whitcomb et al. 1981; Wilcove and Whitcomb 1983), has prompted concern for the continued survival of many forest bird species inhabiting these areas.

Development of island biogeographic theory and species-area relationships (MacArthur and Wilson 1963, 1967) have spawned numerous attempts to evaluate the effects of forest fragmentation on bird populations. Within the United States, these studies have mainly focused on declining populations of many forest songbirds in the deciduous forest biome of eastern North America.

According to the equilibrium theory of biogeography, the number of species on an island is a balance, or dynamic equilibrium, between immigration and extinction rates. This equilibrium point is determined primarily by island size and degree of isolation from sources of potential colonists. The original focus on oceanic islands has been expanded and

applied to terrestrial habitats to assist in understanding the effects of fragmentation. Disjunct patches of terrestrial habitats are depicted as "islands surrounded by a sea" of disturbed or otherwise unsuitable terrain. For example, in the eastern United States where only patches of the once continuous unbroken tract of deciduous forest remain, many species of songbirds, particularly forest dwelling species, are disappearing from those patches (Lynch 1987).

In an examination of Maryland bird distributions, Whitcomb et al. (1981) focused on the relationship between insularity of patches of eastern deciduous forest and composition of forest-associated bird communities. Extensive bird surveys in 1974 and 1975 clearly indicated that different avifaunal assemblages occupied small isolated forest fragments when compared to extensive forest systems. These surveys indicated that neotropical migrants and forest interior specialists were less "tolerant" to fragmentation and were most likely to suffer population declines. In a similar study in Illinois, Graber and Graber (1983) found that transient warbler species utilized a fragmented site in Illinois less frequently than an unfragmented site. In Georgia, Yaukey (1992) found that although several migratory species did not avoid foraging in a disturbed site, their habitat usage was restricted compared to resident species.

Lovejoy et al. (1986), in an on-going and long term study (over 20 years) of the Minimum Critical Size of Ecosystems project (Lovejoy 1980) of the World Wildlife Fund and Brazil's National Institute for Amazon Research, examined not only area effects of fragmentation but also the edge-related changes in the Amazonian forest as it is cleared for pasture. Preliminary results indicate an extensive set of effects generated by a newly created edge including microclimatic changes, consequent vegetation changes,

and a depression in abundance and richness of neotropical forest birds. As the magnitude and complexity of edge-related changes have become more apparent, more attention has been accorded them in recent works.

Both wildlife and land managers have traditionally applauded the virtues of forest edge since the 1930's when Leopold (1933) first reported greater wildlife diversity at edges. The tendency for greater species abundance and richness along edges, known as the "edge effect", results from greater vegetative heterogeneity and simultaneous availability of two different habitat types (Yahner 1988). Although the beneficial effects of edges to certain wildlife (especially game species) have been known for some time, recent emphasis on plant and nongame wildlife conservation has revealed many undesirable impacts associated with edges (Gates and Gysel 1978; Wilcove et al. 1986; Lovejoy et al. 1986; Ratti and Reese 1988; Harris 1984; Yahner 1988). Many of these investigators now refer to the negative consequences of the abrupt creation (due to timber harvest disturbance) of a sharp edge along a previously undisturbed forest.

Increased edge can be detrimental to species dependent upon extensive undisturbed areas and those particularly vulnerable to the high incidence of nest predation and parasitism typically associated with forest edges. Other edge related effects include changes in the physical fluxes across the landscape following forest fragmentation (Lovejoy et al. 1986; Saunders et al. 1991). Typically, the forest edge will experience drastically different microclimatic conditions as a result of altered fluxes of radiation, wind, and water balance. Lovejoy et al. (1986) reported that tropical vegetation within two meters of the edge was visibly affected within days following forest cutting. The consequences of increasing solar radiation at the edges of forest remnants are still not clear; however, shade-tolerant species may become restricted to the

interior parts of the remnant, with different species requiring different distances from the edge for suitable habitat (Saunders et al. 1991). This may account for the distinct sets of "interior" and "edge" species which have been recognized in landscapes, as in eastern North America, that have been fragmented for a long time (Ranney et al. 1981).

Temple (1986) reported that negative impacts associated with edge habitat in deciduous forests in eastern North America extended into the forest for at least 100 meters while Wilcove (1985) reported that edge-related increase in nest predation extended 300-600 meters into the forest. Conversely, in northern Idaho, Ratti and Reese (1988), found no relationship between distance from edge and predation rate. They postulated that because of the natural and highly dynamic disturbance regimes of high elevation environments of the northern Rocky Mountains, abundant edges, formed by natural fragmentation, are a more typical feature in the landscape. Therefore, interior forest species in this area may be adapted to edge-related effects. In the Beartooth Mountains of Wyoming, Norment (1991) found few bird species that were strongly affected by habitat fragmentation, and concluded that edge may be a better predictor, than forest area, of species richness in a naturally fragmented region.

Research to date on fragmentation and edge-related effects in the northern Rocky Mountains has provided few answers on issues of practical importance to management due to the disproportionate amount of research that has been conducted on these processes in eastern deciduous forests compared to western coniferous forests. Because many neotropical migrants use these forests for breeding purposes, it is important on a continental scale to know the effects of forest fragmentation on avian populations in the northern Rocky Mountains.

CHAPTER 2

STUDY AREA and METHODS

Study Area

Site Selection

The study area is located in T4S, R6E, Secs. 22, 26, and 27 approximately 33 km (21 mi) south of Bozeman, Montana (Figure 3). The sites are to the southwest of Hyalite Reservoir, in the northern Gallatin Range, of the Gallatin National Forest. These sites were selected in consultation with United States Forest Service (U.S.F.S.) personnel, an extensive search of aerial photographs and U.S.F.S. stand exam data files, and ground reconnaissance. The criteria used for selection of the study sites were: (1) sites which had undergone two different types of timber harvesting activity, (2) an unlogged "control" site of at least 40 ha (100 acres) to assure an adequate amount of interior forest habitat, and (3) logged and unlogged stands adjacent to each other so that an edge existed.

A total of six stands, three logged and three unlogged, were selected for study. Two of the stands, totaling 51 ha (127 acres), were clear-cut logged in 1964 by the U.S.F.S. (hereafter these "stands" are viewed as one "stand type") creating a relatively abrupt edge with the unlogged forest. A single stand comprises a second logged stand type. It is located on private land (owned by Big Sky Lumber) and was cut in 1972. This stand underwent a different

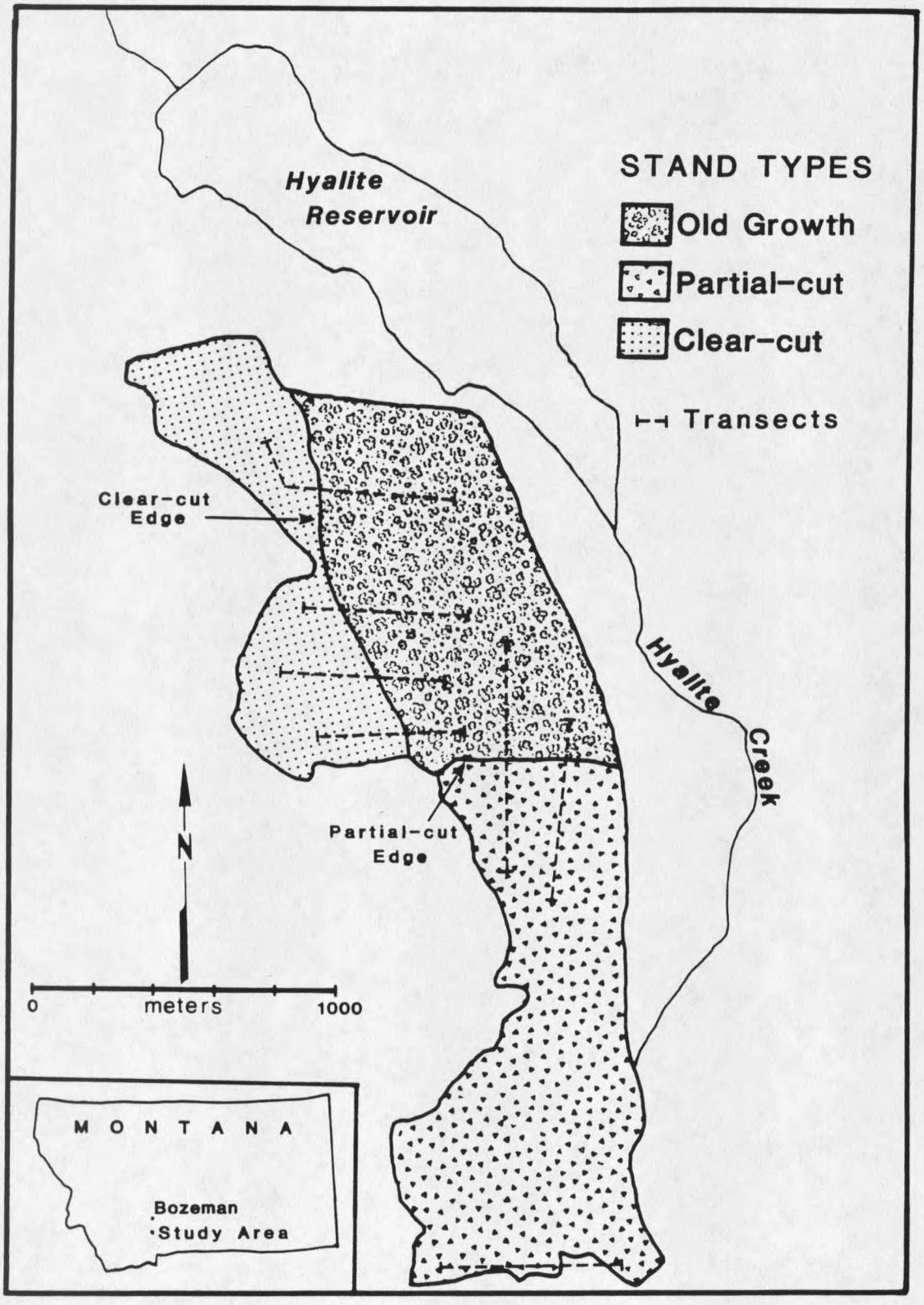

Figure 3. Map of the project area located at the southwestern end of Hyalite Reservoir.

harvest method and is considered by the U.S.F.S. to be a "sloppy clear-cut" or partial cut because not all trees were harvested; only trees deemed merchantable were taken (i.e., "pickle-picking"). This partial-cut created more of a gradual edge along the unlogged forest. Both logged "stand types" sit adjacent to an area designated by the U.S.F.S. as old-growth forest. This expanse of forest (consisting of three stands but hereafter referred to as one stand type) contains an area of 129 ha (322 acres).

Site Descriptions

Elevation ranges between 2066 m (6780 ft) and 2304 m (7560 ft) within the study area and the sites are north-and northeast-facing (Table 1). Percent slope is approximately 20% although parts of all stands exceed a 40% slope, indicating a very broken or benched terrain.

Table 1. General landscape characteristics of the three stand type interiors.

Stand Type	Elevation (m)	Aspect	Slope (%)	Area (ha)	Year logged
Clear-cut	2244	NE	25	51	1964
Partial-cut	2149	N	20	80	1972
Old-growth forest	2105	NE	15	129	unlogged

Subalpine fir (*Abies lasiocarpa*) is the dominant tree species in the old-growth and partial-cut stands whereas sapling lodgepole pine (*Pinus contorta*) dominates the clear-cut stand. Understory vegetation for all stand types include grouse whortleberry (*Vaccinium scoparium*), blue huckleberry (*Vaccinium globulare*), twinflower (*Linnaea borealis*), pinegrass (*Calamagrostis rubescens*), and heartleaf arnica (*Arnica cordifolia*). Following

the habitat type classification system of Pfister et al. (1977), the U. S. F.S. has classified the old-growth and partial-cut sites as *Abies lasiocarpa/Linnacea borealis* (ABLA/LIBO) habitat types in the *Vaccinium scoparium* (VASC) phase. The clear-cut logged stand is classified as both *Abies lasiocarpa/Vaccinium globulare* (ABLA/VAGL) and *Abies lasiocarpa/Vaccinium scoparium* (ABLA/VASC) habitat types.

Soils on all sites are moderately well to well drained (except in scattered seeps and depressions) with medium to moderately fine textures and subsoil clay accumulations. Moist, forested surfaces are acidic to very acidic sandy loams and silts. All sites contain a Cryoboralf soil type (Davis and Shovic 1984). Bedrock consists of Jurassic through Lower Cretaceous sandstone and mudstone of the Swift, Morrison, and Kootenai Formations. The old-growth forest also contains Tertiary andesite outcrops with interbedded sandstone, mudstone, and conglomerate (Chadwick and McMannis 1965). Steep slopes, weathered bedrock, and past logging practices have rendered the area prone to considerable landslide activity (personal observations).

Climatological information (Table 2), obtained from the Lick Creek SNOTEL station located approximately 5 km (3.1 mi) from the study area, indicates a typical continental, mountain climate. Information on the fire history of the area is lacking. The last large fire (stand replacing) known to occur in the Gallatin Range was in 1890 which probably affected the Hyalite drainage (Ed Leritz, U.S.F.S., personal communication 1993). The subalpine fir/Engelmann spruce timber types characteristic of the study area develop in cool, moist locales where the fire frequency of large fires is typically 150 years or more (Arno 1980; Fischer and Clayton 1983). The partial-cut unit shows evidence of fire prior to harvest although no documented information exists. The U.S. Forest Service currently operates under a one hundred percent

suppression effort in the Hyalite drainage. Within the last 20 years there have been numerous small fires of less than one acre in size; approximately half caused by lightning and half human related (Ed Leritz, U.S.F.S., personal communication 1993). There is a relatively high incidence of small fires in the canyon because of the additional ignition source related to increased human use of the area.

Table 2. Mean monthly temperature, precipitation, and snow depth for the Lick Creek SNOTEL station. Data provided by the Soil Conservation Service, Bozeman, Montana.

	Temperature			Precipitation			Snow Depth		
Season	7 yr. avg. °C	1991 °C	1992 °C	30 yr. avg. cm	1991 cm	1992 cm	30 yr. avg. cm	1991 cm	1992 cm
Monthly Mean (Jan.-Dec.)	2.19	2.17	3.08	7.4	6.9	6.6	64.8	96.5	57.7
Breeding Bird Season (May-July)	9.9	9.3	9.3	8.4	6.1	11.9	41.9	121.9	45.7

Timber harvesting operations began in Hyalite Canyon as early as 1877 by George Flanders who floated logs down Middle Creek (referred to as Hyalite Creek today) to his sawmill based at the mouth of the canyon (Gilchrist 1941). Small scale logging operations continued into the turn of the century when "tie hackers" harvested railroad ties from the canyon. By the 1940's, major commercial clear-cutting by private (Burlington Northern) and federal (U.S.F.S.) land owners was well underway. To date, approximately 140 million board feet of timber have been harvested from the Hyalite drainage (Steve Martel, U.S. F. S., personal communication 1993).

Recreational use of the canyon was also prevalent during the early part of the century. The Chisholm cabin, still present today and located on the east

side of Hyalite Reservoir, was built in 1906 (Gilchrist 1941). The original wagon road constructed by George Flanders was improved and the Chisholm family used the cabin as a summer recreational jaunt and entertainment center. Today, Hyalite Canyon is the most heavily used drainage on U.S. Forest Service lands in Montana and Idaho (Jerry Fertney, Idaho Pole, personal communication 1993). Hyalite Reservoir, built in 1951 and now accessible via a paved road, is the closest body of water to the city of Bozeman that is large enough for boating. Additionally, the surrounding landscape, replete with alpine lakes and waterfalls, provides a beautiful setting for camping, hiking, fishing, and winter sports.

Data Collection Methods

Breeding Bird Survey

The bird survey technique used was based on a fixed-radius point count method described and implemented by Hutto et al. (1986). Bird populations were surveyed within 100 m radii circles centered at fixed points. Permanent count points were located 200 m apart along randomly placed transects. Transects originated within the logged area, crossed through the forest-edge, and terminated at least 300 m into the forest interior. Transects were a minimum of 200 m apart from one another. Each count point was marked at the center with a small orange stake. Survey flagging was tied to tree branches at intervals between points to aid the observer in locating the center of the next point. This was especially useful in locating points in the dense, old-growth forest. All birds heard and/or seen within a 10-minute time period at each count point were recorded. Bird counts included birds in flight

over the point and any birds that flushed when the observer approached the point. Utmost care was taken to count an individual bird only once and to avoid repeated counts of the same bird.

During the 1991 breeding season birds were surveyed between 6:30 and 11:30 a.m. between June 5 and July 10. There were a total of 6 transect lines containing 28 count points. All points were visited a total of 10 times. To insure detection consistency, an attempt was made to reverse the direction of visitation of points from that of the previous day. To minimize observer bias in detection rates and assure the counting of unfamiliar birds, bird songs were recorded in the field whenever possible.

During the 1992 breeding season, birds were surveyed between 6:00 and 11:00 a.m. between June 1 and June 21. The earlier morning survey hours during the 1992 season were due to the drier and warmer weather conditions of the 1992 season compared with those of 1991. Temperatures hovered around freezing with several feet of snow still on the ground during the initial phase of the 1991 season whereas the 1992 season was characterized by warmer temperatures and no snow cover. Thus, birds were found to be more active at an earlier hour during the second season. Some count points of the previous year were deleted while others were added in an effort to minimize large differences in sample sizes within the different stand types. Thus, during the 1992 season an additional transect line was included, but the number of count points remained the same. One further addition during the 1992 season included recording whether birds were within the harvested half or forested half of circles which included an edge.

Vegetation Data Collection

Vegetation was sampled within the 100 m radius surrounding each bird observation point by a fixed area plot method. Data collection was split between the two study years. During the 1991 field season, ten randomly selected plots were located within the 100 m radius surrounding each bird observation point. Each plot had a radius of 3.59 m (11.78 ft) containing an area of 1/100 of an acre (0.004 ha). Thus, vegetation was sampled in 1/10 of an acre (0.04 ha) for each bird observation point. To compensate for unnecessary data collection, this strategy was modified in 1992 to include only five randomly selected plots, therefore reducing the area sampled to 1/20 of an acre (0.02 ha).

Within each plot, all trees and snags greater than 15.2 cm (6 in) in height were identified and recorded. Diameter at breast height (d.b.h.) was determined with a diameter-tape measure for each tree over 1.4 m (4.5 ft) in height. Tree height was estimated with the use of a 7 m stick. Forest overstory density was measured from the center of each plot by a spherical densiometer. Percent cover was estimated for trees, shrubs, forbs, graminoids, downed wood, moss cover, and bare ground. Tree and shrub cover were recorded by height classes: mature, pole, sapling and seedling tree classes, and tall and low shrub classes. The criteria for size classes were adapted from U.S.F.S recommendations and are as follows: Mature trees were defined as those having a d.b.h. of at least 15.2 cm (6 in); poles were those trees with a d.b.h. greater than 3.8 cm (1.5 in) but less than 15.2 cm (6 in); saplings were greater than 1.2 m (4 ft) in height with a d.b.h. of less than or equal to 3.8 cm (1.5 in); seedlings were those trees that were less than or equal to 1.2 m (4 ft) in height. Tall shrubs were defined as those at least 0.6 m (2 ft) in height.

Data Analysis Methods

Bird Data Analysis

In order to test for differences in average species abundance by stand type, all points were categorized into one of five stand types: clear-cut interior, partial-cut interior, clear-cut edge, partial-cut edge, and old-growth forest. Average species abundance at a point was calculated by taking the total bird abundance for that point and dividing this number by the total number of visitations. The resulting mean species abundance per survey visit by stand condition is a relatively accurate estimate of bird abundance in the area. Because an active, individual bird can inadvertently be counted twice during a survey visit, calculating mean bird abundance per survey visit was deemed more accurate than simply calculating mean bird abundance for the entire survey period.

To interpret the two factors of interest (stand type and year), a two-way analysis of variance was conducted in order to assess: (a) average differences among stand types (over years), (b) average differences between years (over stand types), and (c) year by stand interaction (to determine whether the effect of year was different among the different stand conditions). If differences between mean bird abundance existed among different stand types, a series of t-tests (linear contrast comparisons) was performed to determine the stand type(s) that were different. If differences between years were detected, paired t-tests within each stand type were conducted to determine which stand types differed between years with respect to average bird abundance and richness. For all tests, a p-value equal to or less than 0.05 was considered significant. Statistical analyses were performed with the use of MSU Stat for the IBM

computer (Lund 1991) and Minitab for the Macintosh computer (Schafer and Farber 1992) statistical software packages.

Similarly, in order to test for differences in species richness between different stand types, points were grouped by stand type and the mean species richness per survey point was calculated. A two-way analysis of variance was used to test for statistically significant differences among the five population means. If a difference was found, then a series of t-tests were performed to locate the stand type(s) that were different.

In order to evaluate differences in bird species composition among the different stand types, bird species were individually grouped into one of four foraging guilds and one of four nesting guilds. Associations between bird communities and environmental features, such as vegetation structure, is biogeographically effective when these communities are evaluated in such functional terms as feeding strategies and nesting habits (Vale et al. 1982; Parker 1987). Guilds were adapted from descriptions by Ehrlich et al. (1988) of foraging techniques and nest locations of birds known to regularly breed in North America. Foraging techniques are the major methods each species uses to obtain food during the breeding season. Although there are many possible foraging guild classifications, only four were chosen for the purposes of this study: (1) ground gleaners (forage primarily by picking up items from the surface of the ground), (2) foliage gleaners (glean invertebrates and/or fruits from foliage and occasionally from branches), (3) bark gleaners (glean from tree trunks and branches, including excavating and drilling into bark), and (4) aerial foragers (use some kind of flying technique to acquire food). This last guild includes flycatchers and birds of prey.

Nesting guilds are delineated by the primary location a species will place its nest. Again four nesting guilds were chosen for the purposes of this

study: (1) ground nesters (nest among the roots, or in niches among the roots of fallen trees, among grasses, on bare rock, or simply scraped in the soil), (2) shrub nesters (nest within any multi-stemmed woody plant), (3) conifer or broad-leaf tree nesters (nest in either coniferous or broad-leafed trees), (4) cavity nesters/snag user guild (nest in cavities of standing dead trees and occasionally in live trees). This last guild includes both primary and secondary cavity nesters. After each species was assigned to a foraging and nesting guild, differences in mean number of birds in each guild per survey visit by stand type were tested for significance using two-sampled t-tests.

Vegetation Data Analysis

All vegetation characteristics measured in the vegetation plots were summarized by stand type. Total trees per acre (0.4 ha) was calculated by dividing the total number of trees recorded by the total plot area. Similarly, trees per acre was calculated for each tree species present: subalpine fir, Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), whitebark pine (*Pinus albicaulis*), Douglas fir (*Pseudostuga menziesii*), and for standing snags. Two-sampled t-tests were used to test for differences among the different stand types. Visual estimation of percent cover of all trees, shrubs, forbs, graminoids, downed dead wood, moss cover, and bare ground were also summarized by stand condition, as was overstory canopy density. Mean d.b.h. and height were also generated for each tree class by stand type.

CHAPTER 3

RESULTS

A total of 50 species (Table 7 in Appendix) were seen and/or heard in the study area, 43 of which were recorded in the 1991-1992 breeding bird survey (Table 3). This avian community is typical of other Rocky Mountain spruce-fir forests (Smith 1980). Of the species recorded during the survey, 33 are neotropical migrants, although parts of some populations will winter in Montana and other parts of the United States. Eleven species winter in the neotropics exclusively (Table 7 in Appendix).

Average Bird Abundance by Stand Type and Year

Average bird abundance over both 1991 and 1992 was significantly different between the five stand classes ($p < 0.0001$). Average bird abundance in the partial-cut interior was found to be significantly greater ($p < 0.0001$) than in the clear-cut interior and significantly greater ($p = 0.0031$) than in the forest interior (Figure 4). Likewise, average abundance in the forest interior was significantly greater ($p < 0.0001$) than the clear-cut interior. Average bird abundance, therefore, was greatest in the partial-cut interior and least in the clear-cut interior.

Average bird abundance in the partial-cut interior was also found to be significantly higher ($p \leq 0.05$) than the clear-cut edge and average abundance in the clear-cut edge was significantly higher ($p = 0.0009$) than the clear-cut

Table 3. Number of birds seen per visit by stand type, 1991 and 1992 breeding seasons.

SPECIES (common regional name)	Forage Guild	Nest Guild	Clear-cut Interior	Partial-cut Interior	Clear-cut Edge	Partial-cut Edge	Old-growth Forest
Mallard	GG	GR	0.00	0.00	0.00	0.00	0.01
Cooper's hawk	AF	CB	0.00	0.01	0.01	0.00	0.00
Red-tailed hawk	AF	CB	0.02	0.03	0.03	0.07	0.00
American kestrel	AF	CN	0.00	0.00	0.00	0.02	0.00
Ruffed grouse	GG	GR	0.05	0.00	0.00	0.04	0.04
Northern flicker	GG	CN	0.05	0.24	0.13	0.22	0.06
Red-naped sapsucker	BG	CN	0.00	0.00	0.00	0.00	0.01
Hairy woodpecker	BG	CN	0.02	0.05	0.07	0.04	0.06
Three-toed woodpecker	BG	CN	0.00	0.00	0.04	0.00	0.04
Olive-sided flycatcher	AF	CB	0.05	0.23	0.19	0.09	0.03
Western wood-pewee	AF	CB	0.00	0.00	0.00	0.00	0.01
Dusky flycatcher	AF	SH	0.22	0.51	0.07	0.16	0.01
Tree swallow	AF	CN	0.00	0.01	0.00	0.00	0.00
Gray jay	GG	CB	0.03	0.04	0.07	0.09	0.03
Clark's nutcracker	FG	CB	0.03	0.24	0.13	0.11	0.05
Common raven	GG	CB	0.00	0.11	0.00	0.00	0.03
Mountain chickadee	FG	CN	0.03	0.68	0.36	0.64	0.86
Brown creeper	BG	CB	0.00	0.01	0.04	0.02	0.08
Red-breasted nuthatch	BG	CN	0.00	0.56	0.43	0.62	1.06
Golden-crowned kinglet	FG	CB	0.00	0.00	0.01	0.04	0.27
Ruby-crowned kinglet	FG	CB	0.05	1.08	0.65	0.60	1.02
Mountain bluebird	GG	CN	0.37	0.00	0.03	0.00	0.00
Townsend's solitaire	FG	GR	0.27	0.00	0.03	0.07	0.00
Swainson's thrush	FG	SH	0.02	0.75	0.25	0.49	0.49
Hermit thrush	GG	GR	0.00	0.15	0.08	0.07	0.03
American robin	GG	CB	0.35	0.35	0.40	0.33	0.28
Warbling vireo	FG	CB	0.00	0.23	0.08	0.11	0.01
Yellow-rumped warbler	FG	CB	0.20	1.61	0.77	1.44	1.06
MacGillivray's warbler	FG	SH	0.00	0.28	0.20	0.13	0.01
Wilson's warbler	FG	GR	0.00	0.05	0.17	0.07	0.00
Chipping sparrow	GG	CB	0.47	0.23	0.32	0.11	0.01
Dark-eyed junco	GG	GR	1.08	1.01	1.16	0.98	0.79
White-crowned sparrow	GG	SH	0.50	0.00	0.27	0.00	0.00
Lincoln's sparrow	GG	GR	0.08	0.17	0.25	0.33	0.01
Brewer's blackbird	GG	CB	0.00	0.01	0.00	0.00	0.00
Western tanager	FG	CB	0.02	0.23	0.31	0.31	0.28
Pine siskin	FG	CB	0.88	1.29	1.21	1.13	1.32
Red crossbill	FG	CB	0.08	0.31	0.39	0.04	0.10
White-winged crossbill	FG	CB	0.00	0.00	0.03	0.00	0.00
Pine grosbeak	FG	CB	0.00	0.09	0.05	0.00	0.06
Cassin's finch	GG	CB	0.00	0.03	0.01	0.00	0.00
Lazuli bunting	GG	SH	0.02	0.00	0.00	0.00	0.00
Unidentified - pecking woodpeckers	BG	CN	0.00	0.09	0.05	0.09	0.14

Foraging Guilds: AF - aerial forager; BG - bark gleaner; FG - foliage gleaner; GG - ground gleaner.

Nesting Guilds: CN - cavity nester/snag user; CB - conifer or broadleaf tree nester; GR - ground nester; SH - shrub nester.

interior. No significant differences were found between the partial-cut edge and clear-cut edge (p = 0.5400), partial-cut interior and partial-cut edge (p = 0.0890), clear-cut edge and forest interior (p = 0.7300), or partial-cut edge and forest interior (p = 0.5400).

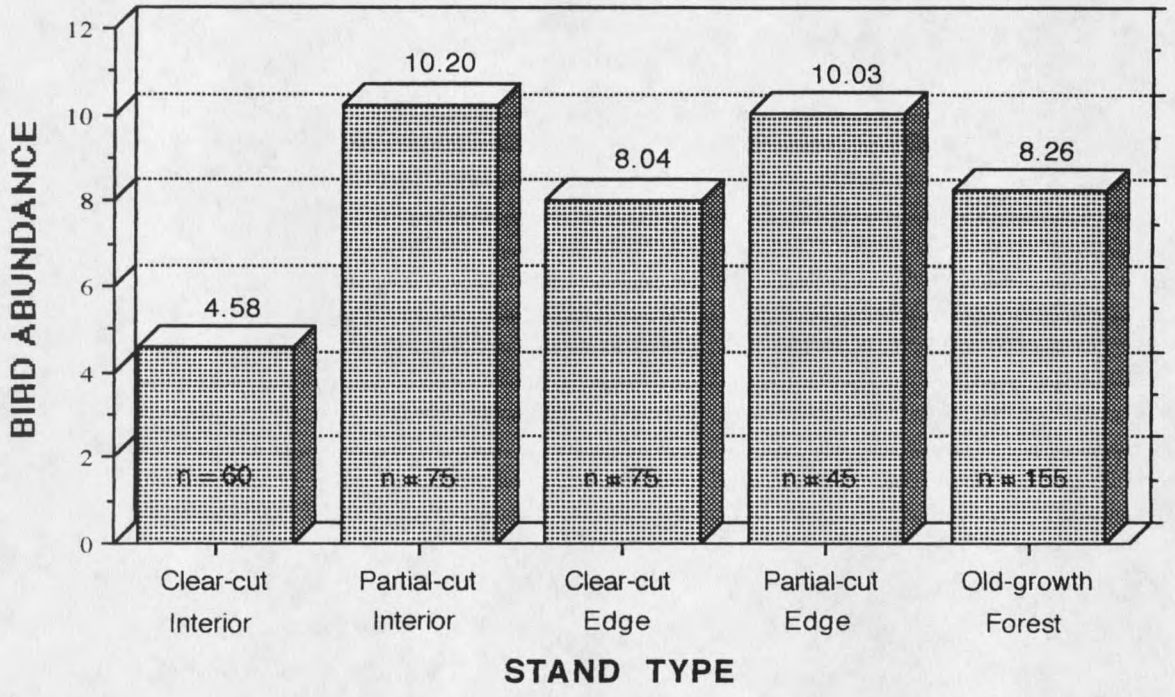

Figure 4. Mean bird abundance per survey visit by stand type, 1991-1992.

Analysis of average species abundance over all stand classes indicated significant differences between 1991 and 1992 (p = 0.0288). Results (Figure 5) indicated significant decreases in average abundance (1991>1992) in the partial-cut interior (p = 0.0476) and clear-cut interior (p = 0.0250). No significant change was detected in the forest interior between years (p = 0.6414) or between the two edge types (p = 0.9215). No significant interaction between stand type and year was detected (p = 0.1482).

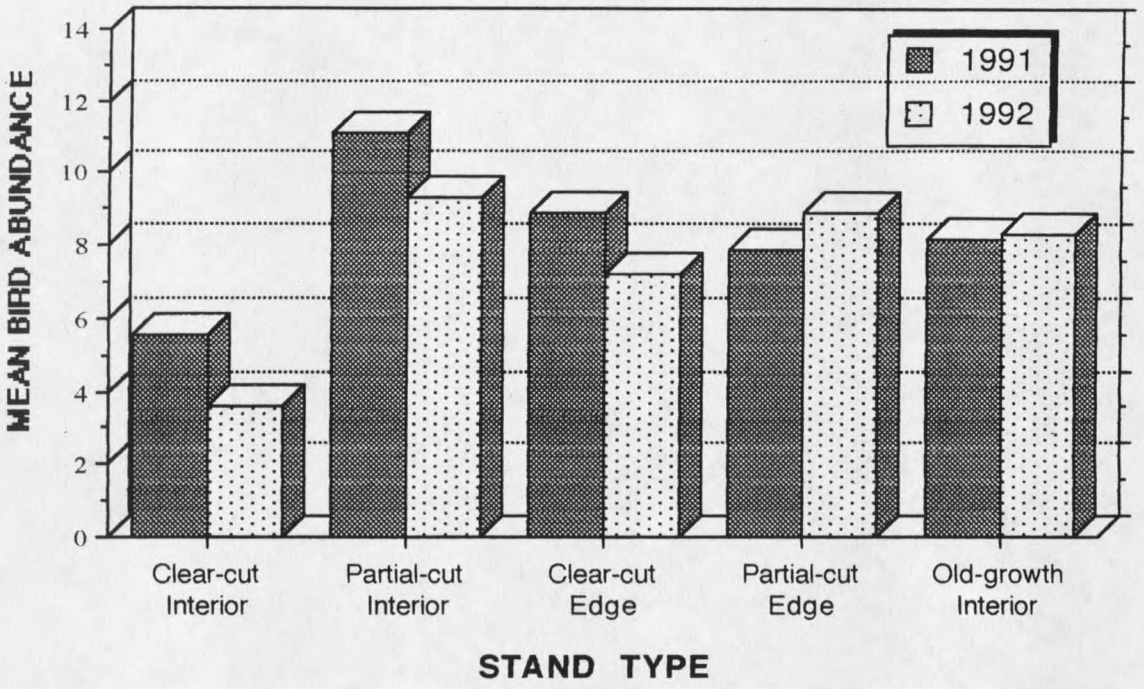

Figure 5. Yearly variation in mean bird abundance, 1991-1992.

Average Species Richness by Stand Type and Year

Average species richness over both 1991 and 1992 was significantly different between the five stand types ($p < 0.0001$). Mean species richness in the partial-cut interior was found to be significantly greater than in the clear-cut interior ($p < 0.0001$) and forest interior ($p < 0.0001$) (Figure 6). Likewise, bird richness in the forest interior was significantly greater than the clear-cut interior ($p = 0.0025$) (i.e., partial-cut > forest > clear-cut with respect to stand interiors and bird diversity). Mean species richness in the partial-cut interior was significantly greater than the partial-cut edge ($p = 0.0077$) and marginally greater than the clear-cut edge ($p = 0.0654$) . Bird species richness within the clear-cut interior was significantly lower than along either the partial-cut or

clear-cut edges ($p < 0.0001$) . Richness within the forest interior was also significantly lower than along either of the edges ($p = 0.0061$). No significant differences were found between the partial-cut and clear-cut edges ($p > 0.0500$).

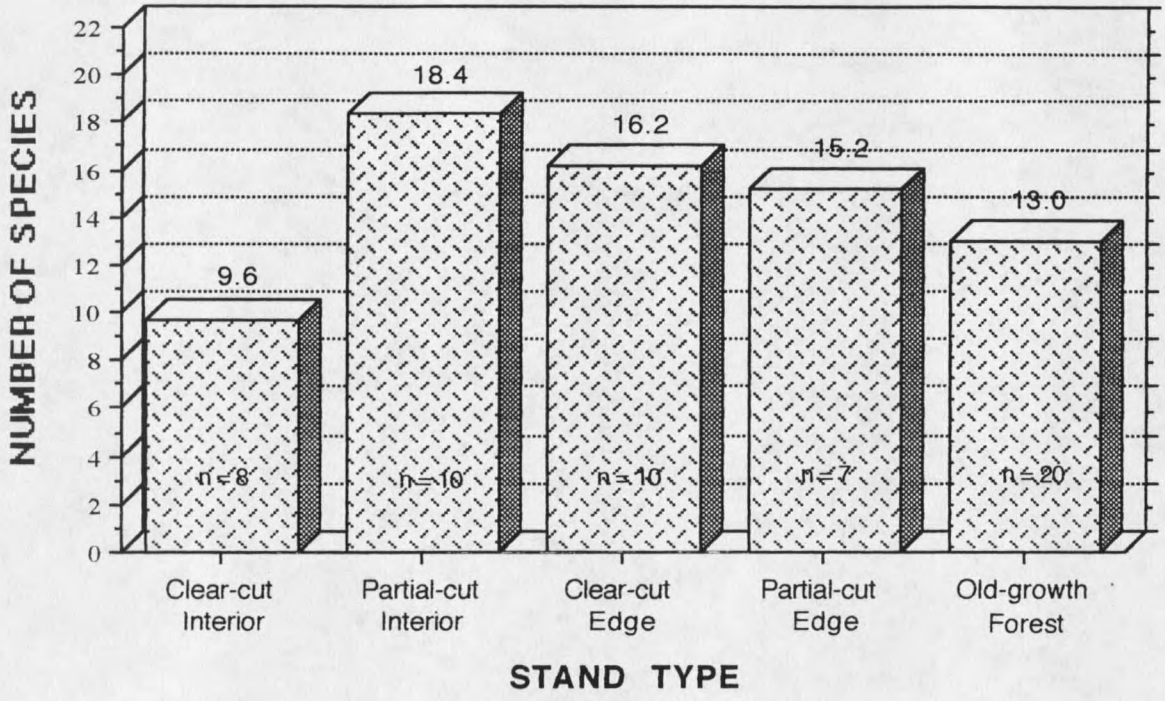

Figure 6. Mean species richness per survey plot by stand type, 1991-1992.

Analysis of mean species richness over all stand classes indicated significant differences between 1991 and 1992 ($p < 0.0001$). Results (Figure 7) indicate significant decreases in species richness (1991>1992) in the partial-cut interior ($p = 0.0125$), clear-cut interior ($p = 0.0500$), and forest interior ($p = 0.0149$). No significant interaction between stand type and year was detected ($p = 0.3584$).

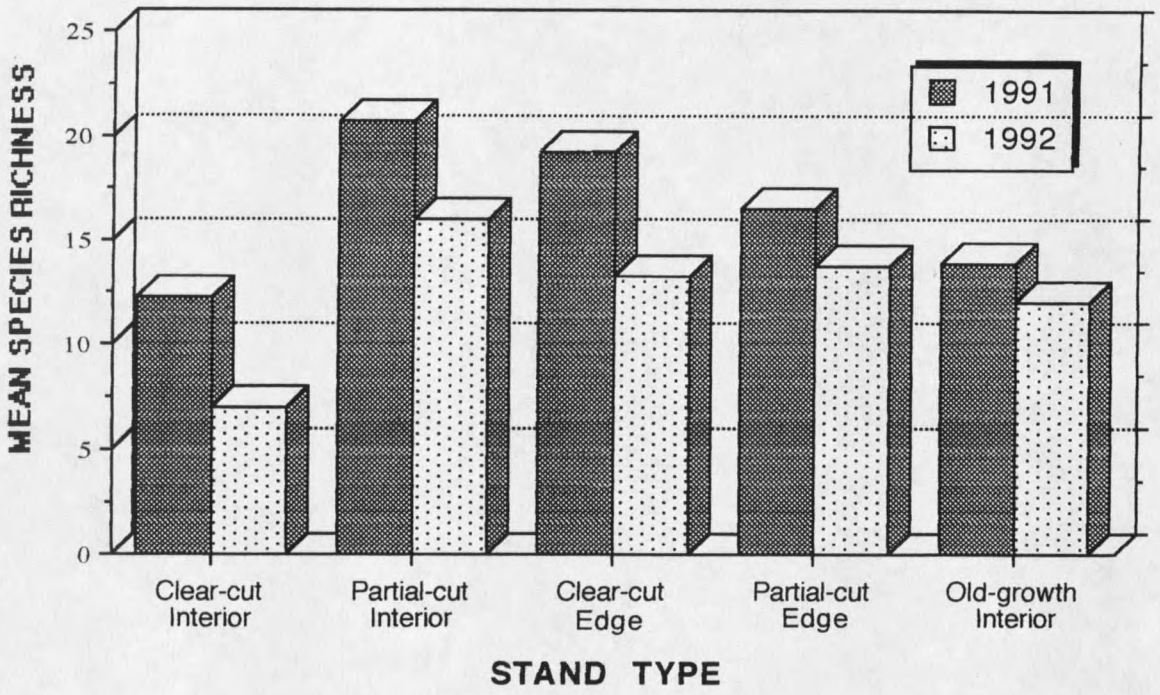

Figure 7. Yearly variation in mean species richness, 1991-1992.

Guild Structure

When each bird species was grouped into foraging and nesting guilds, significant differences were found among the different stand types (Table 4). Among the foraging guilds (Figure 8), foliage gleaners and aerial foragers were significantly more abundant in the partial-cut than in any other stand type ($p = 0.0029$). Foliage gleaners and bark gleaners were least abundant in the clear-cut than in any other stand type ($p = 0.0060$). In contrast, ground gleaners preferred the clear-cut over the partial-cut and old-growth forest ($p = 0.0034$). Bark gleaners were significantly more abundant in the forest than in any other stand type ($p = 0.0060$). No significant differences were found between the two edge types with respect to the foliage gleaners, bark gleaners, and aerial foragers ($p = 0.6900$), but ground gleaners were found to be more

abundant in the clear-cut edge than in the partial-cut edge ($p = 0.0240$). Ground gleaners and aerial foragers preferred either edge type over the forest ($p = 0.0009$), while foliage gleaners and bark gleaners preferred the forest than either edge habitat ($p = 0.0160$).

Table 4. Mean number of birds per survey visit by foraging and nesting guilds and stand types.

Guild	# spp.	Clear-cut Interior	Partial-cut Interior	Clear-cut Edge	Partial-cut Edge	Old-growth Forest
Foraging						
Bark gleaner	6	0.02	0.72	0.61	0.78	1.39
Aerial forager	7	0.28	0.80	0.29	0.33	0.05
Foliage gleaner	15	1.58	6.75	4.60	5.20	5.48
Ground gleaner	15	3.00	2.33	2.72	2.18	1.29
Total	43					
Nesting						
Conifer/broadleaf nester	21	2.18	6.12	4.71	4.51	4.59
Cavity nester/snag user	10	0.47	1.65	1.07	1.64	2.24
Ground nester	7	1.48	1.39	1.69	1.56	0.88
Shrub nester	5	0.75	1.53	0.79	0.78	0.50
Total	43					

Among the nesting guilds (Figure 9), conifer or broadleaf nesters and shrub nesters were significantly more abundant in the partial-cut than in any other stand type ($p = 0.0038$). Cavity nesters were more abundant in the forest than in any other stand type ($p = 0.0026$) and less abundant in the clear-cut than in any other stand type ($p = 0.0001$). Likewise, conifer or broadleaf nesters were least abundant in the clear-cut than in any other stand type ($p < 0.0001$). In contrast, ground nesters utilized the harvested units more than the forest ($p = 0.0002$). No significant difference was found along either of the

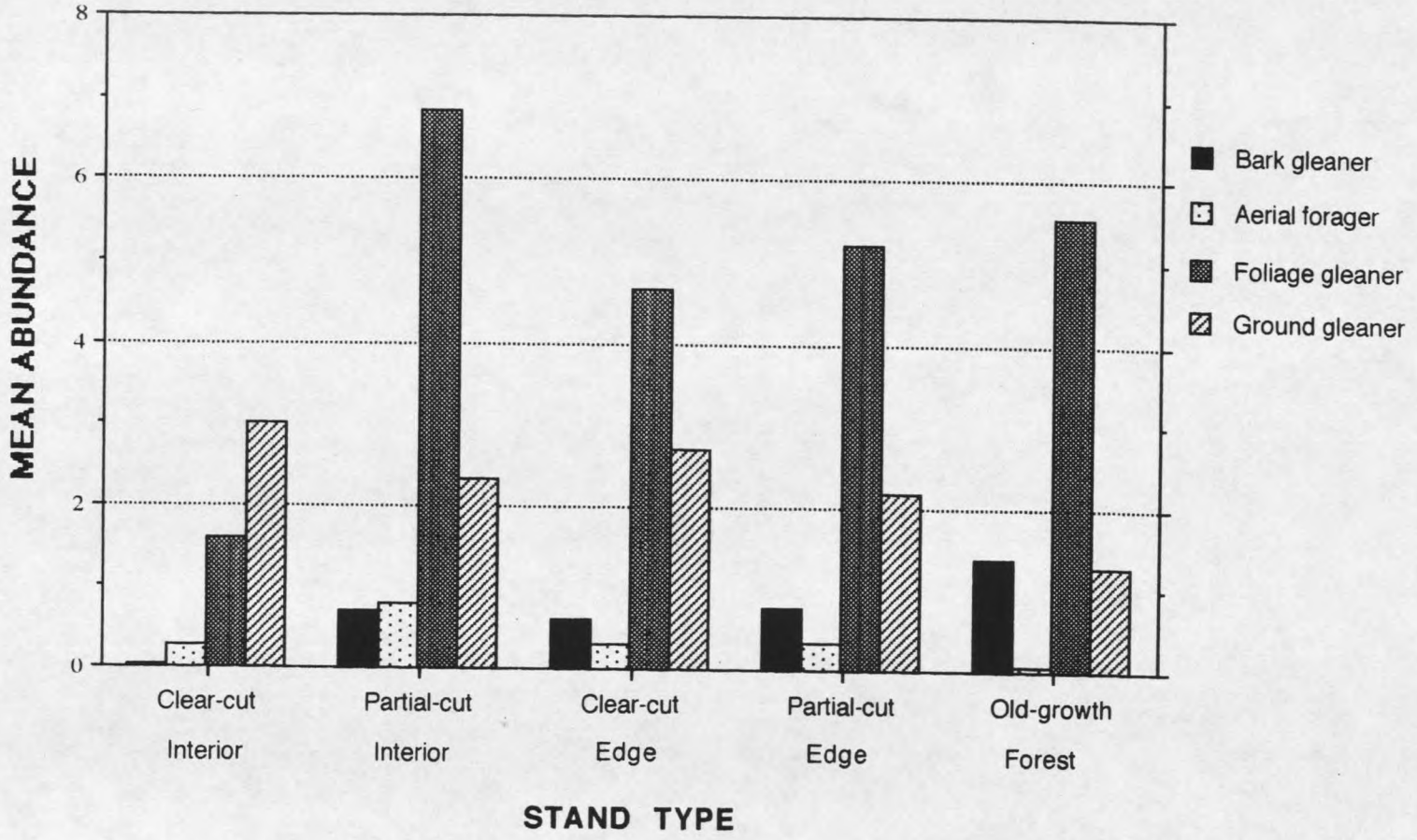

Figure 8. Mean bird abundance per survey visit by foraging guild.

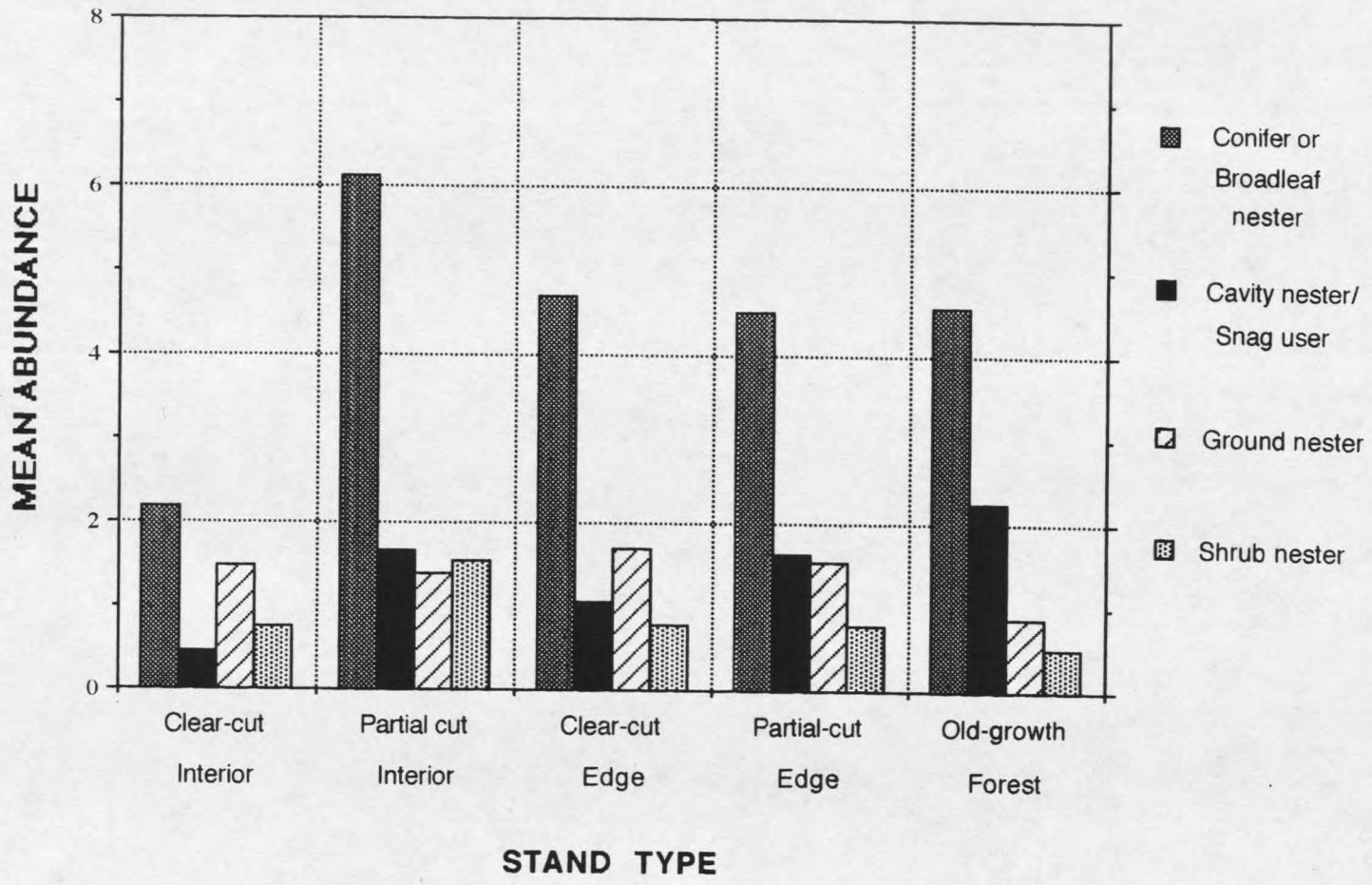

Figure 9. Mean bird abundance per survey visit by nesting guild.

edge types with respect to tree, ground, and shrub nesters ($p = 0.5100$), although cavity nesters preferred the partial-cut edge over the clear-cut edge ($p = 0.0140$). Both ground and shrub nesters were more abundant along the edges than in the forest interior ($p = 0.0280$). Cavity nesters, however, preferred the forest habitat ($p = 0.0026$).

Vegetation Characteristics by Stand Type

The number of trees per acre (0.4 hectare), within each of the four size classes, differed significantly among the different stand types (Figure 10). The partial-cut contained a significantly higher number of saplings and poles than any other stand type ($p = 0.0010$) while the highest numbers of mature trees were found in the old-growth forest compared to the other stand types ($p = 0.0076$). The number of seedlings was similar among the different stand types ($p = 0.6290$).

Tree species composition also varied in the different stand types (Table 5). Subalpine fir was the dominant tree species in both the partial-cut and old-growth forest. Douglas fir was the most abundant tree in the clear-cut, although 88% of these trees occur as seedlings. Few had reached the pole class, and no mature Douglas fir were observed in the clear-cut. Lodgepole pine appeared to be the prevalent tree species in the clear-cut because of the more even representation of this species among the different size classes.

Percent cover of the overstory and understory vegetation differed among the different stand types (Table 6). The overstory canopy density followed a linear pattern with the old-growth forest having the most dense overstory (72.2%) and clear-cut having the least (8.7%). The partial-cut and its

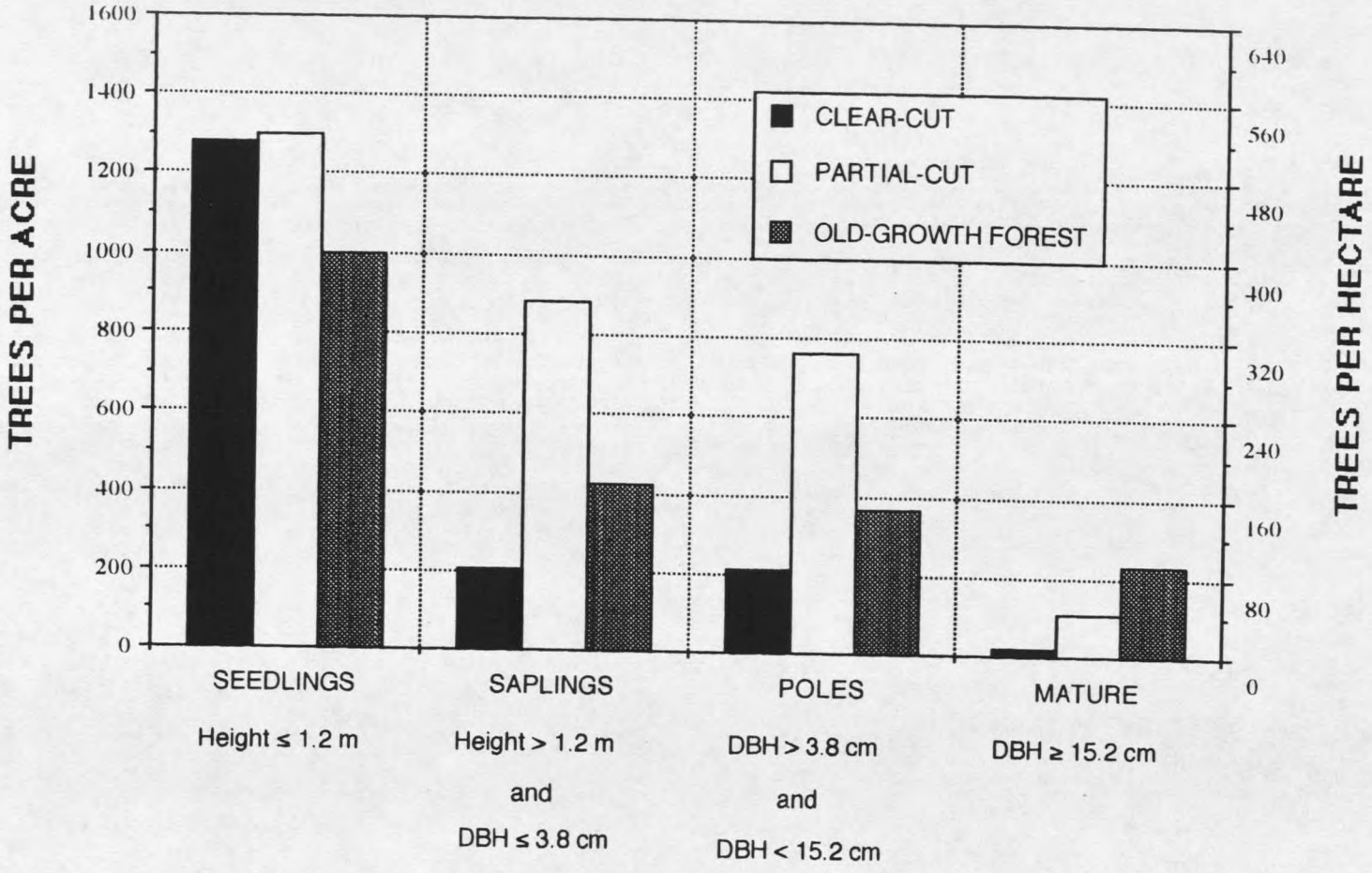

Figure 10. Number of trees per acre/hectare by size class and stand interiors.

Table 5. Number of trees per acre by tree species (common name), tree class, and stand type.

Tree Class	subalpine fir	Englemann spruce	lodgepole pine	whitebark pine	Douglas fir	snags	Total
			CLEAR-CUT INTERIOR				
Seedlings	305	383	83	80	428	0	1279
Saplings	70	28	45	13	53	0	209
Poles	20	10	173	3	8	0	214
Mature	0	0	20	0	0	0	20
Total	395	421	321	96	489	0	
			PARTIAL-CUT INTERIOR				
Seedlings	828	282	50	24	110	4	1298
Saplings	560	118	114	18	58	18	886
Poles	392	52	266	6	38	10	764
Mature	48	24	16	0	2	16	106
Total	1828	476	446	48	208	48	
			CLEAR-CUT EDGE				
Seedlings	446	210	104	8	44	0	812
Saplings	170	40	46	6	12	6	280
Poles	126	20	108	2	0	6	262
Mature	10	8	10	0	2	4	34
Total	752	278	268	16	58	16	
			PARTIAL-CUT EDGE				
Seedlings	590	186	72	26	166	22	1062
Saplings	168	58	236	4	28	16	510
Poles	140	38	248	0	10	34	470
Mature	54	40	40	0	24	54	212
Total	952	322	596	30	228	126	
			OLD-GROWTH FOREST				
Seedlings	528	310	1	18	126	19	1002
Saplings	164	164	0	2	8	81	419
Poles	216	88	2	0	3	57	366
Mature	72	84	39	0	2	30	227
	980	646	42	20	139	187	

associated edge habitat had the greatest amount of shrub cover while the clear-cut and clear-cut edge contained a greater abundance of forbs and grasses. Moss was most frequently found in the old-growth forest. The amount of dead wood and bare ground were similar among the different stand types.

Table 6. Percent cover of overstory and understory vegetation within each stand type.

Vegetation Characteristic	Partial-cut Interior	Clear-cut Interior	Partial-cut Edge	Clear-cut Edge	Old-growth Forest
Seedling tree cover	11.8	8.3	12.0	5.4	12.2
Avg. d.b.h. (cm)	-	-	-	-	-
Avg. height (m)	0.8	0.6	0.7	0.7	0.6
Sapling tree cover	14.8	5.1	9.9	3.6	8.2
Avg. d.b.h. (cm)	2.0	1.6	2.0	1.7	1.9
Avg. height (m)	2.1	1.8	2.2	1.9	2.1
Pole tree cover	30.0	9.2	11.5	13.8	13.3
Avg. d.b.h. (cm)	7.1	6.7	7.0	7.6	7.7
Avg. height (m)	4.9	3.7	5.0	5.0	6.3
Mature tree cover	11.3	2.0	20.1	11.0	36.0
Avg. d.b.h. (cm)	23.8	21.4	30.4	29.0	30.9
Avg. height (m)	16.6	5.4	18.1	16.9	19.2
Overstory canopy density	34.9	8.7	53.1	26.2	72.2
Tall shrub cover	5.9	2.7	7.6	1.5	2.0
Low shrub cover	27.0	19.0	28.0	7.3	18.0
Forb cover	20.9	33.7	32.0	37.1	24.7
Grass cover	18.4	40.5	26.7	44.5	11.6
Moss cover	3.8	8.4	5.8	5.1	20.0
Dead wood cover	19.4	15.7	14.0	18.6	21.4
Bare ground	13.6	16.1	10.5	17.1	11.0

CHAPTER 4

DISCUSSION AND CONCLUSIONS

Discussion

Average Bird Abundance and Richness: Stand Interiors

When comparing the three stand interiors, average bird abundance was significantly higher in the partial-cut than in both the clear-cut and old-growth. Similarly, mean species richness was found to be significantly higher in the partial-cut than in either the clear-cut or old-growth. Because the partial-cut harvesting method took only those trees that were "deemed merchantable", patches of old-growth trees were retained. The presence of seed trees throughout the cut apparently provided ample seeds for regeneration. The partial-cut contains habitat characteristics of both open, cut-over areas, and areas interlaced with old-growth and regenerating trees. The diversity of habitat attributes found in the partial-cut harvest is perhaps the major factor influencing these bird distributions. In northwestern Montana, Tobalske et al. (1991) found similar results when comparing a partial-cut with clear-cut and unlogged areas (although statistical significance of bird abundance and diversity by stand type in their study was not determined).

Because of the diversity in tree structure within the partial-cut, edge habitat is abundant. Mills et al. (1991) suggest that the high vegetation

volume found along edges explains the high bird densities found at the interfaces between habitat types. This could explain the similarity in mean bird abundance found between the partial-cut interior (10.2 per survey visit) and partial-cut edge (10.0 per survey visit). Although a significant difference in mean species richness was found between the partial-cut interior and partial-cut edge, the total number of species seen in these two stand types was quite similar (31 and 29 species, respectively). In a four-year study conducted in the Bridger Mountains of southwestern Montana, Moore (1991) also found relatively high bird abundance and diversity in a structurally diverse shelterwood cut where some standing live trees and snags were retained, thereby creating gradual, irregular edges. Overall, average bird abundance and richness documented in this study were highest in the old-growth stand.

In contrast to the partial-cut, the clear-cut had the lowest mean bird abundance and species richness. These results may be explained by the lack of vegetation and habitat complexity found in the clear-cut. The clear-cut exhibits a homogeneous nature compared to the heterogeneity of the other stands. For example, 75% of the trees in the clear-cut are seedlings compared to less than 50% seedlings in the other stand types. The clear-cut contains only 1% mature trees, all of which are lodgepole pine growing on a gentler slope of the cut. In contrast, the other stands have a higher percentage of mature trees and include multiple species. The same pattern exists when comparing the percentage of trees within the pole size class. Although other investigators document similar low bird abundances and diversity in clear-cuts (i.e., Szaro and Balda 1979; Moore 1991), Tobalske et al. (1991) found that the retention of some snags and live trees of several species mitigated some of the adverse effects of clear-cutting. MacArthur and MacArthur (1961) first suggested the linkage between avian community structure and vegetation

structure and complexity when they reported a strong correlation between bird species diversity and foliage height diversity. Some investigators have since confirmed the usefulness of this theoretical relationship (i.e., Karr and Roth 1971; Willson 1974), while others examined different correlates of avian dynamics and vegetation characteristics such as foliage volume (Anderson et al. 1983; Verner and Larson 1989), individual plant species density (Rice et al. 1984; Rotenberry 1985), total percent vegetative cover (Beissinger and Osborne 1982), and total vegetation volume (Goldstein et al. 1986; Mills et al. 1989,1991). Results suggest a strong correlation between patterns of bird use and patterns of vegetation alteration.

Average Bird Abundance and Richness: Stand Edges

Average bird abundance and species richness did not differ significantly between the partial-cut and clear-cut edges. This does not support the hypothesis that a difference between the two edge types exists because of the more gradual nature (hence, greater diversity of vegetation) of the partial-cut edge compared to the abruptness of the clear-cut edge. Vegetation data substantiate the greater vegetation coverage found along the partial-cut edge compared to the clear-cut edge, but there was no positive relationship with measured bird abundance and richness. Although the partial-cut edge did have a higher average bird abundance, the clear-cut edge had a higher average species richness and a higher number of total species (35 compared to 29). Because the juncture between the two vegetation zones along the partial-cut edge does not span as great a habitat difference as that along the clear-cut edge, there may be a smaller range of microhabitats along the partial-cut edge. Hence, an abrupt edge, with a greater degree of structural contrast, may have

more microhabitats available for a variety of species than a gradual edge (Hansen and Peterson 1989). In northern Idaho, Ratti and Reese (1988) compared nest predation and parasitism rates in an abrupt (due to a clear-cut) and feathered edge (due to partial timber removal), and found that predation in the abrupt edge was greater than in the feathered edge. They postulated that the greater vegetative complexity found along the feathered edge simulated more natural conditions, and that birds were poorly adapted to abrupt, artificial edge habitats. Gates and Gysel (1978) proposed that abrupt, artificial edges function as "ecological traps" because these sites, which offer structural cues to nesting birds, at the same time subject birds to greater rates of nest predation and parasitism. Typical nest predators, however, such as the brown-headed cowbird, Steller's jay, and gray jay were either absent or relatively rare in the Hyalite study area, suggesting that predation does not, at least presently, have a significant effect on local avian population dynamics.

Average bird abundance was significantly greater in the partial-cut interior than along the clear-cut edge, and higher (although not statistically significant) in the partial-cut interior than the partial-cut edge. Average species richness was also significantly higher in the partial-cut interior than along either edge. Again, the hospitable nature of the partial-cut interior is probably due to the presence of a variety of habitats including early successional habitats, several edge types with varying degrees of structural complexity, and patches of older trees. In contrast, the clear-cut interior was significantly lower in average bird abundance and richness than along either edge type. Although the clear-cut provides habitat for some birds with affinities for early seral stages, the data suggest it is a relatively poor habitat for avian communities.

Average bird abundance did not differ significantly between the old-growth forest and either edge type, but average species richness was significantly lower in the forest than along either of the edges. Overall, these results both support and negate the well known "edge effect" maxim where species abundance and richness is thought to be especially high in the ecotones between plant communities. In a review of nine field studies addressing the edge effect which were suitable for comparison, Hansen and Urban (1989) found an equal number of studies in which bird abundance and species richness were either lower or higher along edges than in forest interiors. Some studies documented no difference between the two habitats. Collectively, these results suggest that patterns of abundance and richness along edges are attributable to a myriad of complex and interacting factors which vary in space and in time. Presently, these differing research results make rendering a consensus on edge effects difficult.

Year to Year Fluctuations

The differences in bird abundance and richness from 1991 to 1992 may be due to population regulation by a multitude of complex and interacting factors. It is difficult to isolate one single factor that is responsible for annual changes in bird abundance and richness. Several other studies have also shown year to year fluctuations in bird community dynamics (Szaro and Balda 1979; Franzreb and Ohmart 1978; Tobalske et al. 1991; Moore 1991). In the White Mountains of Arizona, Franzreb and Ohmart (1978) hypothesized that a late snowpack in early spring was responsible for annual variations in species composition and density. Hejl et al. (1988) also attributed depressed bird numbers to a heavy snowfall year in the Sierra Nevada of California.

Similar adverse climatic conditions were prevalent in the spring of 1991 in the Hyalite drainage, but not in 1992. In contrast, bird abundance and richness decreased from 1991 to 1992 despite more amiable weather conditions and improved observer bird identification skills during the second year of study.

Tobalske et al. (1991) attributed annual variations in their two year study to a time-lag effect following logging. Although the original logging operations in the Hyalite drainage were conducted in the early 1960's and 1970's, timber stand improvement (thinning) was conducted in the clear-cut stand at the end of the 1991 breeding season (August). This late season disturbance was coeval with additional timber thinning along the perimeter of Hyalite reservoir and construction associated with the improvement of Hyalite dam at the end of the 1991 breeding season and throughout the 1992 breeding season. The interaction of these disturbances may account for the declines in bird abundance and species richness.

Guild Structure

Changes in vegetative structure due to silvicultural practices may alter the habitat enough to cause a shift in the bird species composition of an area. An examination of avian guild structure provides an understanding of the fundamental factors that influence animal communities (Vale et al. 1989). Results of this study are similar to those previously reported (i.e., Titterington et al. 1979; Crawford et al. 1981; Niemi and Hanowski 1984; Hansen et al. 1992). Bird species composition varied considerably among the different stand types, with the clear-cut attracting bird species that prefer open areas such as ground foragers and ground nesters, and the old-growth supporting

higher numbers of bark gleaners and cavity nesters. The partial-cut provided some elements for both open and closed forest avian species.

Comparison of bird population dynamics noted in this investigation with other studies is inherently problematic due to variation in geographical area, habitat type, harvesting method, and observer expertise. However, population trends of several species appear to follow a common path and, therefore, merit comparison.

Aerial foragers, such as flycatchers and swallows, and ground gleaners, such as juncos and sparrows, were more common in the harvested units than in the old-growth forest. The olive-sided and dusky flycatchers, the two most common aerial foragers in this study, preferred the partial-cut probably because of numerous perch sites found in this edge-like environment. Ground gleaners such as the dark-eyed junco, chipping sparrow, white-crowned sparrow, and the mountain bluebird, were more abundant in the clear-cut than elsewhere. These species are commonly associated with grasslands, similar to habitat provided by clear-cuts. Many ground gleaners are also ground nesters, and thus the abundant slash piles and tall grass in the clear-cut may be additionally attractive to them. Three species of birds, mountain bluebird, Townsend's solitaire (also seen along the partial-cut edge), and lazuli bunting were seen only in the clear-cut despite the presence of what appears to be suitable habitat in the partial-cut interior. Perhaps the low singing voices of these birds caused them to be missed during the survey period in a landscape copious with bird song. Alternatively, perhaps these species are sensitive to patch size and require large, open areas similar to the clear-cut.

Studies conducted in other mountainous regions of Montana have also found many of these species, or similar open-habitat species, to be more

abundant in logged versus unlogged stands (Hejl and Woods 1990; Moore 1991; Tobalske et al. 1991). Similarly, in the White Mountains of Arizona, Franzreb and Ohmart (1978) found greater numbers of aerial foragers and ground gleaners in a selectively-cut harvested area than in an unlogged mixed-coniferous forest. Mannan and Meslow (1984) postulated that the degree of openness appeared to be the most important factor influencing bird densities of those species that were more abundant in managed (85-year old rotation age stands) than old-growth stands in Douglas fir and ponderosa pine (*Pinus ponderosa*) forests of northeastern Oregon. They found that the dusky flycatcher, chipping sparrow, ruby-crowned kinglet, dark-eyed junco and Cassin's finch were attracted to the open structure of the managed stand. These species were more abundant in the harvested stands of this study as well.

Vegetation parameters that distinguished the old-growth stand from the other stand types were the larger number of snags (at least 139 more per acre than the harvested stands) and mature trees, a much denser overstory canopy cover, trees with larger average diameter at breast height, and trees with greater average height. These structural elements are typical of old-growth forests (Franklin et al. 1981) and coincide with attributes used in other studies to quantify vegetation patterns in old-growth compared to earlier seral stages (Hansen et al. 1991).

Several species in this study were found to be closely associated with or perhaps dependent upon old-growth. Bark gleaners and cavity nesters such as the red-naped sapsucker, hairy woodpecker, three-toed woodpecker, red-breasted nuthatch, brown creeper, and mountain chickadee were more abundant in the old-growth forest than in the other stand interiors (species level statistical analysis, however, was not performed). Of these, the red-

naped sapsucker and three-toed woodpecker were found exclusively in the old-growth. The golden-crowned kinglet, a foliage gleaner, also appeared dependent on old-growth forest. This species was seldom seen in an edge habitat, but if so, it was always far into the unharvested half of the edge (i.e., 30-50 m into the forest).

These patterns of habitat preference appear to coincide with species' habitat needs (i.e. nesting and foraging requirements). The size of the tree or the d.b.h. appears to be an important variable for many species. In western larch (*Larix occidentalis*)-Douglas fir forests of northwestern Montana, for example, McClelland et al. (1979) found that the average d.b.h. required by the cavity nesting species recorded in this study was 50.8 cm (20 in). Mannan and Meslow (1984) found that the proportion of snags used for nesting and foraging substrates increased with the size of the snag. They concluded that the difference in abundance of large snags between managed and old-growth stands was partly responsible for differences in abundances of the red-breasted nuthatch, the brown creeper, and other hole-nesting species. Several studies have also found higher abundances of golden-crowned kinglets in unlogged versus logged stands (Franzreb and Ohmart 1978; Titterington et al. 1979; Mannan and Meslow 1984). In the present study, the golden-crowned kinglet was found to be a very secretive bird, and was heard only in dense sections of the forest. Similarly, Mannan and Meslow (1984) found that this species was positively correlated with high canopy volumes.

Conclusions

Avian community structure and productivity are partially a function of the availability of critical resources (i.e., specific habitat parameters)

associated with temporal and spatial patterns of vegetation. These landscape patterns are increasingly shaped by timber management activities as evidenced by the highly fragmented nature of the landscape surrounding Hyalite Reservoir. Furthermore, these management activities cause relatively substantial changes over relatively short time periods, when compared to the successional changes characteristic of coniferous forests in the northern Rocky Mountains. Avian populations inhabiting this region are shown to be appreciably affected by changes in vegetation structure due to silvicultural practices. Whether these affects are deemed "beneficial" or "detrimental" depends on ecosystem needs, social and economic values, and management objectives. Loss of species sensitive to fragmentation is often offset by gains in species that benefit from early successional growth induced by timber harvesting. Because different birds will respond differently to varying degrees of alteration, management plans to alter existing vegetation should take into account individual species' tolerances to these changes when managing for different bird assemblages.

An examination of community composition by foraging and nesting behavior is an important management tool which can assist land managers in managing for specific species at a landscape perspective. Individual bird species differ in their tolerance to specific habitat alterations. Cavity nesters, for example, show a very low tolerance to the removal of trees and snags because this drastically reduces potential nest sites. Furthermore, selection of snags for nesting by certain species depends on the hardness of the snag. Some primary cavity nesters (those that excavate the cavity themselves), for example, prefer soft snags over intermediate or hard snags (Stauffer and Best 1980), while others prefer harder snags (Moore 1991). Whether the live tree

or snag has a broken or intact top is also an important selection variable (McClelland et al. 1979), as is the size of the tree (Thomas et al. 1979).

The total effect of timber harvest on a bird community will depend upon the magnitude of the logging operation and method of tree removal. The greater mean bird abundance and bird richness in the partial-cut compared to the clear-cut should be of interest to forest managers who want to minimize negative impacts of timber harvesting to forest-dwelling bird species. Although some species preferred the clear-cut over the other stands, there is an ample amount of open habitat provided by wet meadows, tree fall, avalanche paths, campgrounds, and other forms of development in the Hyalite drainage to sustain these species. For those breeding birds that appear particularly sensitive to timber harvest (i.e., three-toed woodpecker, golden-crowned kinglet, brown creeper), management plans need to include designated stands of existing old-growth forest and replacement stands for future old-growth before a harvest is planned.

Because bird populations are reduced in clear-cuts, then determining the maximum slope that could sustain clear-cutting (e.g., that which is still conducive to regeneration within a specified period of time) in fragile high elevation environments such as Hyalite Canyon would be a useful management guideline. Further research also needs to address the long and short term effects of thinning operations on bird communities. Even with these practical insights to forest management, it remains an on-going challenge to continue extensive research on the process of forest fragmentation and its implications to wildlife, and to inject the resultant new understandings to future landscape planning and management decisions. There remains a paucity of time-series data both on landscape patterns and changes of species composition in forest tracts during the course of

fragmentation. In addition, simultaneous short-term analyses of birds in many forest fragments types are needed. To date, temporal analyses have been restricted to longer term studies of single forest types. Establishing a national Geographic Information System data base incorporating regional breeding bird surveys, forest characteristics, and regional land use patterns would greatly aid in the research and understanding of the overall patterns of landscape process and change, as well as help determine management goals for optimal forest cover on a region by region basis.

Although disturbance and natural fragmentation (especially from fire) characterized the landscapes of the northern Rockies during presettlement time, much of the remaining old-growth on the Gallatin National Forest exists in isolated patches, many of which are less than a hundred acres in size. Land management professionals must consider that imperiled species include not only those listed under the Endangered Species Act, but also species whose very existence depends upon sound management and utilizing the concept of sustained yield in governing the use of the region's forest resources.

LITERATURE CITED

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Aldrich, J. W. and C. S. Robbins. 1970. Changing abundance of migratory birds in North America. Smithsonian Contributions to Zoology 26:17-26.

Ambuel, B. and S. A. Temple. 1982. Songbird populations in southern Wisconsin forests: 1954 and 1979. Journal of Field Ornithology 53(2):149-158.

Ambuel, B. and S. A. Temple. 1983. Songbird populations in southern Wisconsin forests. Ecology 64:1057-1068.

Anderson, B.W., R.D. Ohmart, and J. Rice. 1983. Avian and vegetation community structure and their seasonal relationships in the lower Colorado River valley. Condor 85:392-405.

Arno, S.F. 1980. Forest fire history in the northern Rockies. Journal of Forestry 78(8):460-465.

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

Bider, J.R. 1968. Animal activity in uncontrolled terrestrial communities as determined by a sand transect technique. Ecological Monographs 38:269-308.

Blake, J.G. and J.R. Karr. 1987. Breeding birds of isolated woodlots: Area and habitat relationships. Ecology 68(6):1724-1734.

Brittingham, M.C. and S.A. Temple. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33(1):31-35.

Burger, L.D. 1988. Relations Between Forest and Prairie Fragmentation and Depredation of Artificial Nests in Missouri. Master's thesis, University of Missouri-Columbia.

Burgess, R.L. and D.M. Sharpe (eds.). 1981. Forest Island Dynamics in Man-Dominated Landscapes. Springer-Verlag Inc., New York.

Chadwick, R.A. and W.J. McMannis. 1965. Geology of the Bozeman Quadrangle. U.S. Department of Energy (unpublished map).

Crawford, H.S., R.G. Hooper, and R.W. Titterington. 1981. Songbird population response to silvicultural practices in central Appalachian hardwoods. Journal of Wildlife Management 45(3):680-692.

Darby, H.C. 1972. The clearing of the woodland in Europe. Pp. 183- 216 in W. L. Thomas Jr. (ed.). Man's Role in Changing the Face of the Earth. University of Chicago Press, Chicago.

Davis, C. and H.F. Shovic. 1984. Soil Survey of the Gallatin Forest Area, Montana. U.S. Forest Service.

Ehrlich, P.R., D.S. Dobkin and D. Wheye. 1988. The Birder's Handbook: A Field Guide to the Natural History of North American Birds. Simon and Schuster Inc., New York.

Fischer, W.C. and B.D Clayton. 1983. Fire ecology of Montana forest habitat types east of the continental divide. USDA Forest Service General Technical Report INT-141, Ogden Utah.

Franklin, J.F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological Characteristics of Old-Growth Douglas-Fir Forests. USDA Forest Service General Technical Report PNW-118.

Franzreb, K.E. and R.D. Ohmart. 1978. The effects of timber harvesting on breeding birds in a mixed-coniferous forest. Condor 80:431-441.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:871-883.

Gilchrist, L. 1941. Highlights of Hyalite. Unpublished term paper, Montana State University.

Graber, J.W. and R.R. Graber. 1983. Feeding rates of warblers in Spring. Condor 85:139-150.

Goldstein, E.L., M. Gross, and R.M. DeGraaf. 1986. Breeding birds and vegetation: a quantitative assessment. Urban Ecology 9:377-385.

Fertney, J. 1993. Personal communication. Idaho Pole, Bozeman, Montana.

Hansen, A.J., and J.A. Peterson. 1989. Responses of Upland Wildlife Communities to Forest Stand and Edge Type in the Oregon Coast Range. A study plan submitted to the Coastal Oregon Productivity Program (COPE), Oregon State University.

Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L. Ohmann. 1991. Conserving biodiversity in managed forests. Bioscience 41(6):382-392.

Hansen, A.J., D.L. Urban, and B. Marks. 1992. Avian community dynamics: The interplay of landscape trajectories and species life histories. Pp. 173-195 in A.J. Hansen and F. di Castri (eds.). Landscape Boundaries: Consequences for Biotic Diversity and Ecological Flows. Springer-Verlag Inc., New York.

Hansen, A.J. and D.L. Urban. 1989. Species diversity across landscape and biome boundaries. In F. di Castri and A.J. Hansen (eds.). Landscape Boundaries: Consequences for Biodiversity and Ecological Flows. Kluwer Academic Publishers, The Hague, Netherlands.

Harris, L.D. 1984. The Fragmented Forest. The University of Chicago Press.

Hejl, S.J., J. Verner, and R.P Balda. 1988. Weather and bird populations in true fir forests of the Sierra Nevada, California. Condor 90:561-574.

Hejl, S.J. and R.E. Woods. 1990. Bird assemblages in old-growth and rotation-aged Douglas-fir/ponderosa pine stands in the northern Rocky Mountains: A preliminary assessment. In Proceedings of a Symposium on Interior Douglas-fir: The Species and its Management.

Hutto, R.L., S.M. Pletschet, and P. Hendricks. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103:593-602.

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

Leopold, A. 1933. Game Management. Charles Scribner and Sons, New York.

Leritz, E. 1993. Personal communication. U. S. Forest Service, Bozeman, Montana.

Lord, J.M. and D.A. Norton. 1990. Scale and the spatial concept of fragmentation. Conservation Biology 4(2):197-202.

Lovejoy, T.E. 1980. Discontinuous wilderness: minimum areas for conservation. Parks 5(2)13-15.

Lovejoy, T.E., R.O. Bierregaard, Jr., A.B. Rylands et al. 1986. Edge and other effects of isolation on Amazon forest fragments. Pp. 257-286 in M.E. Soule (ed.). Conservation Biology: The Science of Scarcity and Diversity. Sinauer Associates, Inc., Sunderland, Massachusetts.

Lund, R.E. 1991. MSUSTAT Statistical Analysis Package Version 5.00. Montana State University, Bozeman MT.

Lynch, J.F. 1987. Responses of breeding bird communities to forest fragmentation. Pp. 123-140 in D.A. Saunders, G.W.Arnold, A.A. Burbidge, and A.J.M. Hopkins (eds.). Nature Conservation: The Role of Remnants of Native Vegetation.

Lynch, J.F. and D.F. Whigham. 1984. Effects of forest fragmentation on breeding bird communities in Maryland, USA. Biological Conservation 28:287-324.

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

MacArthur, R.H. and E.O. Wilson. 1963. An equilibrium theory of insular biogeography. Evolution 17:373-387.

MacArthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, N.J.

Mannan, R.W. and E.C. Meslow. 1984. Bird populations and vegetation characteristics in managed and old-growth forests, northeastern Oregon. Journal of Wildlife Management 48(4):1219-1238.

Martel, S. 1993. Personal communication. U. S. Forest Service, Bozeman, Montana.

Mayfield, H.F. 1965. The Brown-headed Cowbird, with old and new hosts. The Living Bird 4:13-28.

Mayfield, H.F. 1977. Brood parasitism reducing interactions between Kirtland's Warblers and Brown-headed Cowbirds. Pp. 85-92 in S. A. Temple (ed.). Endangered Birds: Management Techniques for Preserving Threatened Species. University of Wisconsin Press, Madison, WI.

McClelland, B.R., S.S. Frissell, W.C. Fischer, and C.H. Halvorson. 1979. Habitat management for hole-nesting birds in forests of western larch and Douglas-fir. Journal of Forestry 77:480-483.

McLellan, C.H., A.P. Dobson, D.S. Wilcove, and J.F. Lynch. 1986. Effects of forest fragmentation on new-and old-world bird communities: Empirical observations and theoretical implications. Pp. 305-313 in M. L. Morrison and C. J. Ralph Wildlife 2000: Modeling Habitat

Relationships of Terrestrial Vertebrates. University of Wisconsin Press, Madison, WI.

Mills, G.S., J.B. Dunning Jr., and J.M. Bates. 1989. Effects of urbanization on breeding bird community structure in southwestern desert habitats. Condor 91:416-428.

Mills, G.S., J.B. Dunning, Jr., and J.M. Bates. 1991. The relationship between breeding bird density and vegetation volume. Wilson Bulletin 103(3):468-479.

Moore, R.L. 1991. Breeding Birds in Old-Growth Forests/Snag Management for Birds. Bozeman Ranger District, Gallatin National Forest, Montana.

Niemi, G.J. and J.M. Hanowski. 1984. Relationships of breeding birds to habitat characteristics in logged areas. Journal of Wildlife Management 48(2):438-443.

Noon, B.R. and K. Young. 1991. Evidence of continuing worldwide declines in bird populations: Insights from an international conference in New Zealand. Conservation Biology 5(2):141-143.

Norment, C.J. 1991. Bird use of forest patches in the subalpine forest-alpine tundra ecotone of the Beartooth Mountains, Wyoming. Northwest Science 65(1):1-9.

Parker, K.C. 1987. Avian nesting habits and vegetation structure. Professional Geographer 39(1):47-58.

Pfister, R.D., B.L. Kovalchik, S.F. Arno, and R.C. Presby. 1977. Forest Habitat Types of Montana. General Technical Report INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Post, W., T.K. Nakamura and A. Cruz. 1990. Patterns of Shiny Cowbird parasitism in St. Lucia and southwestern Puerto Rico. Condor 92:461-469.

Ranney, J.W., M.C. Bruner and J.B. Leyenson. 1981. The importance of edge in the structure and dynamics of forest islands. Pp. 67-95 in R.L. Burgess and D.M. Sharpe (eds.). Forest Island Dynamics in Man-Dominated Landscapes. Springer and Verlag Inc., New York.

Ratti, J.T. and K.P. Reese. 1988. Preliminary test of the ecological trap hypothesis. Journal of Wildlife Management 52(3):484-491.

Rice, J., B.W. Anderson, and R.D. Ohmart. 1984. Comparison of the importance of different habitat attributes to avian community organization. Journal of Wildlife Management 48:895-911.

Robbins, C.S. 1979. Effect of forest fragmentation on bird populations. Pp. 198-212 in R. M. DeGraaf and K. E. Evans (eds.). Workshop Proceedings: Management of Northcentral and Northeastern Forests for Nongame Birds. USDA Forest Service General Technical Report NC-51.

Robbins, C.S. 1980. Effect of forest fragmentation on breeding bird populations in the Piedmont of the mid-Atlantic region. Atlantic Naturalist 33:31-36.

Rosenberg, K.V. and M.G. Raphael. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. Pp. 263-272 in M.L. Morrison J. Verner and C.J. Ralphs (eds.). Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison, WI.

Rotenberry, J.T. 1985. The role of habitat in avian community composition: physiognomy or floristics? Oecologia 67:213-217.

Saunders, D.A., R.J. Hobbs and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: A review. Conservation Biology 5(1):18-32.

Schaefer, R.L. and E. Farber. 1992. The Student Edition of MINITAB User's Manual. Addison-Wesley Publishing Company, Reading, Massachusetts.

Smith, K.G. 1980. Nongame birds of the Rocky Mountain spruce-fir forests and their management. Pp. 258-279 in Management of Western Forests and Grasslands for Nongame Birds. USDA Forest Service General Technical Report INT-86. Salt Lake City, Utah.

Stauffer, D.F. and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. Journal of Wildlife Management 44(1):1-15.

Szaro, R.C. and R.P. Balda. 1979. Bird community dynamics in a ponderosa pine forest. Studies in Avian Biology 3:1-66.

Temple, S.A. and B.A. Wilcox. 1986. Predicting effects of habitat patchiness and fragmentation. Pages 261-262 in M.L. Morrison J. Verner and C.J. Ralph (eds.). Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. University of Wisconsin, Madison.

Thomas, J.W., R.G. Anderson, C. Maser, and E.L. Bull. 1979. Snags. in J.W. Thomas (ed.). Wildlife Habitats in Managed Forests - The Blue Mountains of Oregon and Washington. U.S. Forest Service Agricultural Handbook No. 553.

Titterington, R.W., H.S. Crawford, and B.N. Burgason. 1979. Songbird responses to commercial clear-cutting in Maine spruce-fir forests. Journal of Wildlife Management 43(3):602-609.

Tobalske, B.W., R.C. Shearer, and R.L. Hutto. 1991. Bird Populations in Logged and Unlogged Western Larch/Douglas-fir Forest in Northwestern Montana. USDA Forest Service Research Paper INT-442.

Vale, T.R., A.J. Parker, and K.C. Parker. 1982. Bird communities and vegetation structure in the United States. Annals of the Association of American Geographers 72:120-130.

Vale, T.R., A.J. Parker, and K.C. Parker. 1989. Terrestrial vertebrates and vegetation structure in the western United States. Professional Geographer 41(4):450-464.

Veblen, T.T. 1987. Biogeography. Pp. 28-46 in G.L. Gaile and C.J. Willmott (eds.) Geography in America. Columbus: Merril Publishing Co.

Verner, J. and T.A. Larson. 1989. Richness of breeding bird species in mixed-conifer forests of the Sierra Nevada, California. Auk 106:447-463.

Whitcomb, R.F., J.F. Lynch, M.K. Klimkiewicz, C.S. Robbins, B.L. Whitcomb, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pp. 125-205 in R. L. Burgess and D. M. Sharpe (eds.). Forest Island Dynamics in Man-Dominated Landscapes. Springer-Verlag Inc., New York.

Wilcove, D.S. 1985. Nest predation on forest tracts and the decline of migratory songbirds. Ecology 66:1211-1214.

Wilcove, D.S., C.H. Mclellan and A P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pp. 237-256 in M. E. Soule (ed.). Conservation Biology: The Science of Scarcity and Diversity. Sinauer Associates, Sunderland, Massachusetts.

Wilcove, D.S. and R.F. Whitcomb. 1983. Gone with the trees. Natural History 9:82-91.

Williams, M. 1989. Americans and Their Forests: A Historical Geography. Cambridge University Press, New York.

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

Yahner, R.H. 1988. Changes in wildlife communities near edges. Conservation Biology 2(4):333-339.

Yaukey, P.H. 1992. Habitat use by migratory birds at a disturbed site. Physical Geography 13(2):149-159.

APPENDIX

Table 7. Cumulative species list with scientific name and wintering range.

COMMON NAME	SCIENTIFIC NAME	WINTERING GROUNDS
Mallard	*Anas platyrhynchos*	WR - ME
Common snipe	*Gallinago gallinago*	WR - CS
Sharp-shinned hawk	*Accipiter striatus*	US - CA
Cooper's hawk	*Accipiter cooperii*	US - CA
Northern goshawk	*Accipiter gentilis*	WR - ME
Red-tailed hawk	*Buteo jamaicensis*	WR - CA
Osprey	*Pandion haliaetus*	US - SA
American kestrel	*Falco sparverius*	WR - CA
Ruffed grouse	*Bonasa umbellus*	WR
Great Horned owl	*Bubo virginianus*	WR
Flammulated owl	*Otus flammeolus*	CA
Northern flicker	*Colaptes auratus*	WR
Red-naped sapsucker	*Sphyrapicus nuchalis*	US - CA
Hairy woodpecker	*Picoides villosus*	WR
Three-toed woodpecker	*Picoides tridactylus*	WR
Olive-sided flycatcher	*Contopus borealis*	CS
Western wood-pewee	*Contopus sordidulus*	CS
Dusky flycatcher	*Empidonax oberholseri*	ME
Tree swallow	*Tachycineta bicolor*	CA
Steller's jay	*Cyanocitta stelleri*	WR
Gray jay	*Perisoreus canadensis*	WR
Clark's nutcracker	*Nucifraga columbiana*	WR
Common raven	*Corvus corax*	WR
Mountain chickadee	*Parus gambeli*	WR
Brown creeper	*Certhia americana*	WR - CA
Red-breasted nuthatch	*Sitta canadensis*	WR - ME
Golden-crowned kinglet	*Regulus satrapa*	US - CA
Ruby-crowned kinglet	*Regulus calendula*	US - CA
Mountain bluebird	*Sialia currucoides*	US - ME
Townsend's solitaire	*Myadestes townsendi*	WR - ME
Swainson's thrush	*Catharus ustulatus*	SA
Hermit thrush	*Catharus guttatus*	US - CA
American robin	*Turdus migratorius*	WR - CA
American dipper	*Cinclus mexicanus*	WR
Warbling vireo	*Vireo gilvus*	MC
Yellow-rumped warbler	*Dendroica coronata*	US - CA
MacGillivray's warbler	*Oporornis tolmiei*	MC
Wilson's warbler	*Wilsonia pusilla*	CA
Lazuli bunting	*Passerina amoena*	ME
Chipping sparrow	*Spizella passerina*	US - ME
Dark-eyed junco	*Junco hyemalis*	WR - ME
White-crowned sparrow	*Zonotrichia leucophrys*	US - ME

Table 7 continued.

COMMON NAME	SCIENTIFIC NAME	WINTERING GROUNDS
Lincoln's sparrow	*Melospiza lincolnii*	US - CA
Brewer's blackbird	*Euphagus cyanocephalus*	US - ME
Western tanager	*Piranga ludoviciciana*	MC
Pine siskin	*Carduelis pinus*	US - ME
Red crossbill	*Loxia curvirostra*	ME
White-winged crossbill	*Loxia leucoptera*	WR
Pine grosbeak	*Pinicola enucleator*	WR
Cassin's finch	*Carpodacus cassinii*	WR - ME

Wintering grounds: WR = Montana winter resident, US = winters in other parts of U.S., ME = Mexico, CA = Central America, SA = South America, MC = ME & CA, CS = CA & SA.