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Bird populations logging and red-naped sapsucker habitat suitability based on fledging success

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BIRD POPULATIONS, LOGGING, AND RED-NAPED SAPSUCKER HABITAT SUITABILITY BASED ON FLEDGING SUCCESS

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Ten species of breeding birds differed in abundance between harvested and adjacent uncut areas following a winter (1988-89) seed tree removal on Coram Experimental Forest in northwestern Montana. Cutting units were relatively small, and some live paper birch (Betula papyrifera), quaking aspen (Populus tremuloides), and black cottonwood (Populus trichocarpa) trees as well as conifer and broadleaf snags were left standing within the cutting units. During the summers of 1989 and 1990, Tree Swallows (Tachycineta bicolor) were abundant in clearcuts and not detected in unlogged stands. Similarly, Dark-eyed Juncos (Junco hyemalis) and Pine Siskins (Carduelis pinus) were more common within clearcut and partially cut habitats than within uncut stands. Golden-crowned Kinglets (Regulus satrapa), Swainson's Thrushes (Catharus ustulatus), Varied Thrushes (Ixoreus naevius), and Townsend's Warblers (Dendroica townsendi) were less abundant in the cut areas. Ruby-crowned Kinglets (Regulus calendula) and Fox Sparrows (Passerella iliaca) were least abundant in both clearcut and contiguous old-growth stands. Chipping Sparrows (Spizella passerina) were common in logged stands and interspersed, unlogged forest, and relatively rare in contiguous old growth.

Foliage-foraging species and tree gleaners were less abundant in harvested areas, whereas flycatching species and ground foragers were more common there. Of the nesting guilds, conifer tree-nesting species were least abundant in clearcuts, and ground nesters were more common within the cutover habitats.

Red-naped Sapsuckers (Sphyrapicus nuchalis) were abundant in logged stands with trees left standing. The number of sapsucker young fledged per nest was positively correlated with the percent of home territory logged and the number of birch and aspen from 10-30 cm dbh within the home territory. Thus, abundance of the birds appeared to reflect the suitability of the habitat for nesting. Additionally, it seems unlikely that retaining some trees useful for nesting and foraging within cutting units will create ecological sinks for Red-naped Sapsuckers.

Negative correlates with fledging success included the number of birch and aspen > 30 cm dbh, canopy height, percent of home territory burned, and number of snags > 30 cm dbh. Values for these variables were highest for home territories within the Red Bench Burn Area of Glacier National Park.

When mitigation for tree-dependent species is an objective, forest managers should retain within cutting units broadleaf trees including paper birch, quaking aspen, and black cottonwood, and snags of all tree species.

PREFACE

Scientific progress is gained by carefully observing patterns and developing tests to help explain those patterns. With this in mind, I studied the effects of timber harvesting upon coniferous forest birds. In Chapter One, I present patterns of abundance that I observed for bird species breeding in logged and unlogged stands of western larch (Larix occidentalis)/Douglas-fir (Pseudotsuga menziesii var. glauca) forest. In general, the patterns were intuitive: conifer-tree nesters were least abundant in clearcuts in which most of the conifer trees were removed, and ground nesters were most abundant there. In contrast, primary cavity nesters that depend upon trees for nesting and foraging were equally abundant in logged and unlogged areas. It was this pattern that I decided to investigate.

It appeared that retaining snags and living paper birch and aspen within the cutting units had mitigated most of the potentially adverse effects of extensive conifer-tree removal for some of the species within the primary cavity nesting guild. I studied reproductive success among Red-naped Sapsuckers (Sphyrapicus nuchalis) to see if the census data accurately reflected habitat quality. In light of the potential for site tenacity among woodpeckers, I also investigated whether or not logged areas with some nesting and foraging trees could function as ecological sinks for Red-naped Sapsuckers (presented in Chapter Two).

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I thank Dr. Richard Hutto, Dr. Raymond Shearer, Dr. B. Riley McClelland, and Dr. Kenneth Dial for their guidance and critical evaluation of this work. Andrea Stephens assisted with locating sapsucker nests and recording time budgets. Joel Carlson, Elaine Caton, and Steve Gniadek also helped locate nests. Debbie Conway, Gina Berkemann, Bettina Gerlemann, Tom O'Brien, Bart Tobalske, and Jean Totebusch assisted with various protions of the field work. James Hasbrouk prepared a pre-timber harvest survey on Coram Experimental Forest that was vital to field planning, and Jack Schmidt provided extensive field and computer support. Dr. Sallie Hejl and Dr. Dave Turner assisted with data analysis. Marilyn Holgate formatted portions of the manuscript, and Bryan Owen created the maps. Funding for this study was provided by the U.S. Forest Service and a Five Valleys Audubon Society 1990 Field Biology Research Award.

CHAPTER 1

BIRD POPULATIONS IN LOGGED AND UNLOGGED WESTERN LARCH/ DOUGLAS-FIR FOREST IN NORTHWESTERN MONTANA

INTRODUCTION

The influence of logging on bird populations during the breeding season has been documented for a variety of forest types in the western United States: mixed conifer (Franzreb and Ohmart 1978; Mannan and Meslow 1984; Verner and Larson 1989), coastal Douglas-fir (Pseudotsuga menziesii) (Hagar 1960; Meslow 1978), interior Douglas-fir (Medin 1985; Medin and Booth 1989), giant sequoia (Sequoiadendron giganteum) (Kilgore 1971), lodgepole pine (Pinus contorta) (Austin and Perry 1979), and ponderosa pine (Pinus ponderosa) (Szaro and Balda 1979).

Medin (1985) provided a summary of bird species' responses to various logging methods based on several of the studies cited above. Although general patterns of response were consistent for many species, certain species, including Yellow-rumped Warbler (scientific names of bird species censused in the study area are in appendix 1) and Hairy Woodpecker were reported to increase, decrease, or show no response following clearcutting. This suggests that studies of bird responses to logging may be spatially or temporally specific. Thus, a need exists for other investigations of the effects of logging on birds, especially in unstudied forest types.

I studied the influence of logging on a wide range of birds in the Coram Experimental Forest, located within the western larch (Larix occidentalis) forest cover type (Eyre 1980). This chapter describes two years of observed differences in the avian assemblage following logging and site-preparation treatments.

STUDY AREA

This study was located within the southern quarter of the Coram Experimental Forest (CEF), about 45 km east of Kalispell, MT, on the Flathead National Forest (fig. 1.1). It included both the Terrace Hill sale area (THSA) and the adjacent Coram Research Natural Area (CRNA) (fig. 1.2).

Description

The site occupied a portion of the watershed drained by the South Fork of Abbot Creek. The THSA ranges in elevation from 1,021 to 1,372 m, lies mostly southwest of Abbot Creek, and is on northeast-facing slopes. The CRNA ranges in elevation from 1,067 to 1,359 m, lies northeast of Abbot Creek, and is mostly on southwest-facing slopes. Slopes of both areas range from 5 to 35 percent. Annual precipitation averages 86 cm. Temperature averages 16 ^{o}C from May through August (Hungerford and Schlieter 1984).

The study area represents a seral stage of the subalpine fir/queencup beadlily (Abies lasiocarpa/Clintonia uniflora) habitat type classified by Pfister et al. (1977). Western larch and Douglas-fir (Pseudotsuga menziesii var. glauca) are the dominant trees on the CEF. The old-growth larch is composed mostly of 300-year-old (and occasionally 500-year-old) trees. Other trees include Engelmann spruce (Picea engelmannii), subalpine fir, lodgepole pine (Pinus contorta),

Figure 1.1--Location of study area within Coram Experimental Forest, northwest Montana.

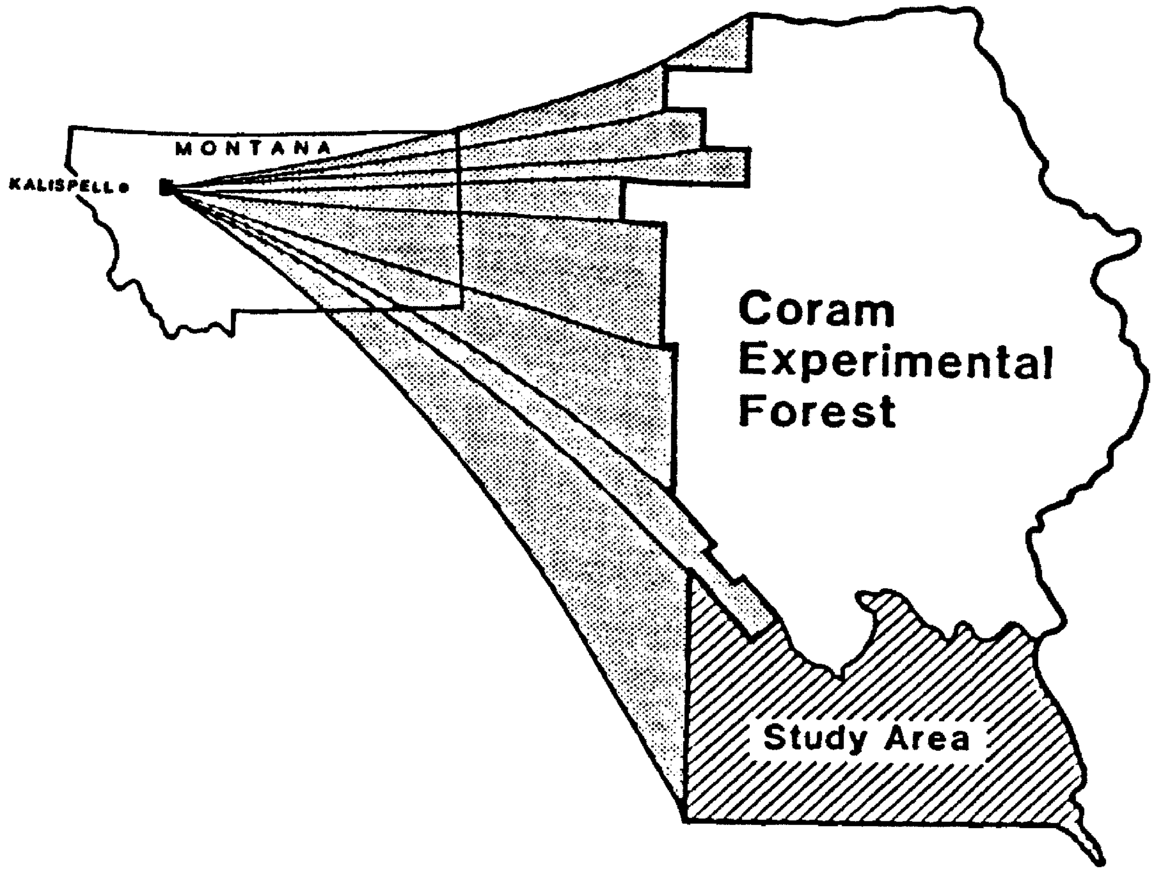
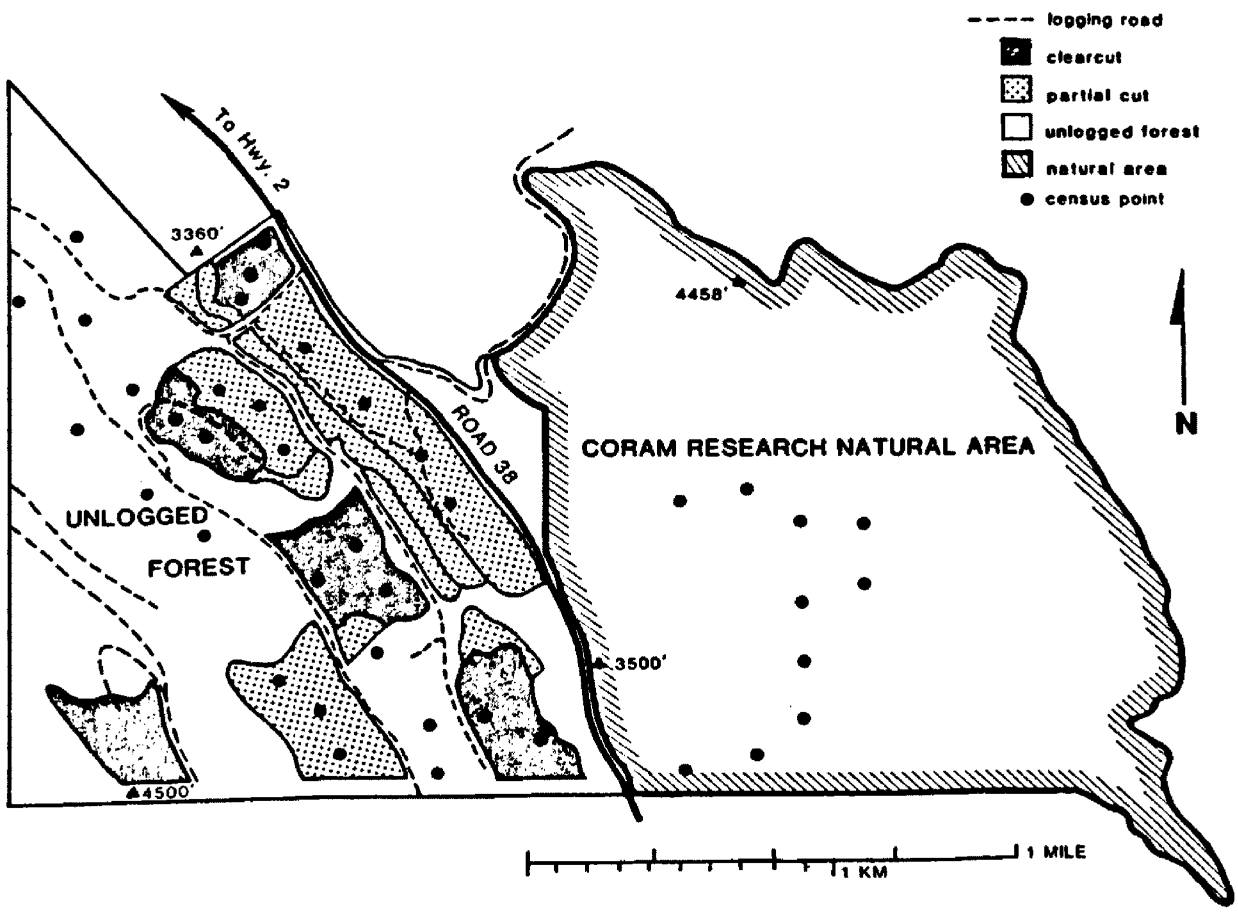


Figure 1.2--Posttreatment stand conditions and location of bird-count/vegetation sampling points on the Terrace Hill sale area and Coram Research Natural Area, Coram Experimental Forest, 1989 and 1990.



western white pine (Pinus monticola), paper birch (Betula papyrifera), quaking aspen (Populus tremuloides), and black cottonwood (Populus trichocarpa). Dominant shrubs include Rocky Mountain maple (Acer glabrum) and fool's huckleberry (Menziesia ferruginea). Queencup beadlily and pinegrass (Calamagrostis rubescens) are the primary herbs.

Treatments

The THSA was initially harvested from 1942 to 1944, leaving three to five seed trees over 31 cm dbh per 0.4 ha (Fredeking 1953). The seed trees and trees that were unmerchantable in the 1940's were removed in the winter of 1988-89 within partial-cut units, and more extensive overstory removal occurred in the clearcut units. Based on guidelines for the management of cavity-nesting birds by McClelland and Frissell (1975), snags of all species of trees, along with living paper birch, quaking aspen, and black cottonwood, were retained in the cutting units during the more recent harvest.

The THSA was 263 ha and included clearcut and partially cut units along with unlogged forest (fig. 1.1). There were five clearcuts ranging from 6 to 14 ha. The largest partial-cut unit was 28 ha, and eight others ranged between 2 and 16 ha. Experimental controls were provided by unlogged forest of 134 ha within the THSA and the adjacent 339-ha CRNA.

Slash piling and scarification of the units was accomplished with a bulldozer in 1989. Most of the slash piles were burned during the autumn of 1989, and sites with slopes greater than 20 percent were broadcast burned in September 1990.

METHODS

Design

During the 1989 and 1990 breeding seasons, bird populations were censused with 100-m radius fixed-point counts. Species detections were by sight or sound, including birds in flight over the plot. During both years, each point was visited on three evenly spaced days between June 1 and July 7. Counts were done between one-half hour after sunrise and 1000 hrs, for a period of 10 min each.

Count points were located with a coordinate grid overlay placed on figure 1.2. After scaling distances between lines on the grid to be 200 m apart on the ground and numbering the points of intersection sequentially, a random-numbers table was read to select 10 points within each of three stand conditions: clearcut, partial-cut, and unlogged forest. Points were selected so that the radius of the plot would not intersect another stand condition. These points defined the census plots on the ground; each was marked at the center with a survey flag.

Because the CRNA (fig. 1.2) was difficult to map accurately, a different method was used there to select census points. Beginning at the southwest corner of the stand, a random number was generated with a pocket calculator to determine a compass bearing. After following this bearing for 250 m, a census plot was centered at the destination. Subsequent plots were selected in the same manner with a new bearing for all 10 points. Bearings that would carry a plot within 100 m of the boundary of the natural area were ignored by returning to the origin and taking a new bearing.

Vegetation was sampled once per year during July 1989 and 1990 at the 10 points in each stand condition that was selected for bird censusing (table 1.1). Sampling followed the guidelines of the Ocular method in Hahn and Jensen (1987) using the General Plot Data and Ocular Plant Species Data forms. Each plot had a 11-m radius, with one plot at the center of each bird-count point. Snags were included in all tree measurements. Tree basal area was estimated with a "Relascope" prism. Percent cover was measured for trees, shrubs, graminoids, and forbs, using horizontal estimates of the vertical projection of each life form. Tree and shrub cover was further sampled at three height categories: pole and larger, sapling, and seedling tree classes, and tall, mid and low shrub classes.

Analysis

The mean count per point for each bird species censused in 1989 and 1990 was calculated by averaging data for the three yearly visits to each point. Because there were 10 points in each stand condition, I obtained 10 average counts for each bird species within each stand condition and year. The mean of each of these 10 averages was used to test for differences in relative abundance of bird species among stand conditions and years. Sampling vegetation components at the census points once per year generated 10 sample values for the selected variables within each stand condition. The mean of each set of 10 samples was compared to the means for the other stands during each year.

Table 1.1--Estimates of vegetation components within each of the four stand conditions at the Terrace Hill study area and adjacent Coram Research Natural Area, Coram Experimental Forest, in 1989 and 1990

Vegetation component	Stand condition				Probability[2]
	Clear-cut[1]	Partial-cut[1]	Unlogged forest	Natural area	
Tree basal area (m^2/ha)	6^{A}	26^{A}	78^{B}	85^{B}	0.001
Tree total cover (percent)	3^{A}	24^{B}	59^{C}	63^{C}	0.001
Pole and larger (percent)	1^{A}	18^{B}	44^{C}	48^{C}	0.001
Sapling (percent)	1^{A}	5^{A}	13^{B}	13^{B}	0.001
Seedling (percent	1	2	2	2	1.000
Shrub total cover (percent)	13^{A}	37^{B}	47^{B}	44^{B}	0.006
Tall[3] (percent)	1^{A}	9^{AB}	10^{AB}	13^{B}	0.016
Mid[3] (percent)	10	22	25	18	0.192
Low[3] (percent)	2^{A}	6^{AB}	12^{B}	12^{B}	0.016
Graminoid total cover (percent)	9	11	6	4	1.000
Forb total cover (percent)	22	18	35	42	0.032

[1]Snags of all species and living paper birch trees were left standing where possible.

[2]Low probability values indicate significantly different means among stand conditions, Bonferroni adjusted to control for experimentwise error (SPSS Inc. 1983); superscript letters group similar means for each vegetation component.

[3]Tall shrub, >10 ft (3 m); midshrub, 2-10 ft (0.6-3 m); low shrub, <2 ft (0.6 m) (Hahn and Jensen 1987).

All bird species seen less than eight times during both years' censusing over all points were arbitrarily excluded from species-level statistical analysis (table 1.2). These species were, however, included in the guild analysis (table 1.3). Statistical significance in all tests was $\underline{P} < 0.05$, employing the Bonferroni adjustment to control for experimentwise error rate (SPSS Inc. 1983). I used two-way analysis of variance to test for significant interaction and main effects for a given species' abundance by stand condition and year (SPSS Inc. 1983). Parametric analysis was justified on the basis of normal probability plots for the common species within the sample. Although count data for rarer species are heavily right-skewed, the analysis of variance procedure is robust for comparison of samples with similar distributions (Sokal and Rohlf 1981).

The same statistical analysis was used on guild populations (table 1.3) and vegetation structure (table 1.1).

RESULTS

Vegetation

Some components of the vegetation varied by stand condition whereas others did not (table 1.1). Obviously the cutover areas had significantly less tree basal area than the uncut controls. The clearcuts had some tree basal area because, where possible, snags of all species and live paper birch were left for use by birds and animals. Percentage of total tree cover (made up of seedlings-, saplings-, and pole- and larger-size trees) significantly increased from clearcut through partial cut to uncut units. Although the pole-size and larger trees followed this pattern, sapling-size trees were not significantly different between the cutover areas. Seedling cover was not significantly different among stand conditions.

Following timber harvest, total shrub cover (percent) on partial-cut and uncut stands was significantly greater than on clearcuts (table 1.1). The tall-shrub and mid-shrub components were decreased substantially on clearcuts compared to partial cuts or the uncut controls. Low shrub cover on clearcuts was significantly less than on the uncut stands, and was intermediate (but not significantly different) on partial cuttings.

Neither the graminoid nor the forb cover was significantly different among the stand conditions after the cutting treatments (table 1.1), but twice as much average graminoid cover occurred on cutover than on uncut areas. Conversely, forb cover within the cutover stands was about half that of the uncut areas.

Birds

I observed 51 bird species during censusing of the study area (appendix 1), but only 32 species were sufficiently abundant to include in the statistical analysis (table 1.2). Pine Siskins and Varied Thrushes exhibited a significant interaction effect between stand condition and year (figs. 1.3-1.4). Significant differences in abundance occurred among stand conditions for 10 species of birds. Tree Swallows were frequently detected in clearcuts, but virtually absent elsewhere. Species that were less abundant in clearcut or partial-cut

Table 1.2--Mean number of birds counted per census point within the four stand conditions at the Terrace Hill study area and adjacent Coram Research Natural Area, Coram Experimental Forest, in 1989 and 1990

Species[1]	Foraging guild[2]	Nesting guild[3]	Stand condition: Clear-cut[4]	Partial-cut[4]	Unlogged forest	Natural Area	Proba-bility[5]
Killdeer	GF	GR	0.15	0.00	0.00	0.00	0.640
Vaux's Swift	FC	SC	0.15	0.07	0.00	0.00	1.000
Red-naped Sapsucker	TD	PC	0.45	0.35	0.27	0.52	1.000
Hairy Woodpecker	TD	PC	0.17	0.13	0.19	0.33	1.000
Northern Flicker	GF	PC	0.22	0.13	0.07	0.18	1.000
Olive-sided Flycatcher	FC	CB	0.17	0.07	0.02	0.00	0.224
Western Wood-Pewee	FC	CB	0.07	0.03	0.05	0.00	1.000
Tree Swallow	FC	SC	0.62^{A}	0.07^{B}	0^{B}	0.00^{B}	0.016
Steller's Jay	FF	CB	0.03	0.05	0.13	0.05	1.000
Common Raven	GF	CB	0.11	0.03	0.10	0.22	1.000
Black-capped Chickadee	TG	SC	0.30	0.27	0.40	0.57	1.000
Mountain Chickadee	TG	SC	0.08	0.17	0.28	0.28	1.000
Red-breasted Nuthatch	TG	SC	0.30	0.42	0.58	0.53	1.000
Brown Creeper	TG	SC	0.00	0.03	0.02	0.12	1.000
Winter Wren	GF	GR	0.00	0.13	0.08	0.17	1.000
Golden-crowned Kinglet	FF	CT	0.00^{A}	0.45^{AB}	0.47^{AB}	0.73^{B}	0.016
Ruby-crowned Kinglet	FF	CT	0.13^{A}	0.52^{B}	0.40^{AB}	0.17^{A}	0.016
Mountain Bluebird	GF	SC	0.13	0.00	0.00	0.03	1.000
Townsend's Solitaire	FF	GR	0.13	0.25	0.00	0.02	0.192
Swainson's Thrush	FF	CB	0.15^{A}	1.05^{B}	1.05^{B}	1.23^{B}	0.002
American Robin	GF	BT	0.58	0.30	0.22	0.05	0.096
Varied Thrush	GF	BT	0.03^{A}	0.05^{A}	0.10^{A}	0.38^{B}	0.016
Solitary Vireo	FF	CB	0.05	0.10	0.07	0.18	1.000
Warbling Vireo	FF	BT	0.13	0.20	0.18	0.18	1.000
Yellow-rumped Warbler	FF	CT	0.28	0.35	0.28	0.25	1.000
Townsend's Warbler	FF	CT	0.43^{A}	1.00^{B}	1.22^{BC}	1.50^{C}	0.002
MacGillivray's Warbler	FF	BT	0.02	0.12	0.13	0.22	0.864
Western Tanager	FF	CT	0.10	0.20	0.10	0.00	0.896
Chipping Sparrow	GF	BT	0.68^{A}	0.72^{A}	0.52^{AB}	0.17^{B}	0.016
Fox Sparrow	GF	GR	0.18^{A}	0.32^{AB}	0.40^{AB}	0.00^{A}	0.016
Dark-eyed Junco	GF	GR	1.27^{A}	0.80^{A}	0.25^{B}	0.13^{B}	0.002
Pine Siskin	FF	CB	0.78^{A}	0.57^{AB}	0.17^{B}	0.08^{B}	0.032
Total No. Species	32	32	29	30	28	25	

[1]Scientific names of bird species are listed in appendix.

[2]Foraging guild: FF - foliage forager; FC - flycatcher; TD - tree driller; TG - tree gleaner; GF - ground forager (Diem and Zeveloff 1980).

[3]Nesting guild: CT - conifer tree; CB - conifer or broadleaf tree; BT - bush or small tree; PC - primary cavity; SC - secondary cavity; GR - ground (Diem and Zeveloff 1980).

[4]Snags of all species and living paper birch trees were left standing where possible.

[5]Low probability values indicate significantly different means among stand conditions, Bonferroni adjusted to control for experimentwise error; superscript letters group similar means for each species (SPSS Inc. 1983).

Table 1.3--Mean number of birds, by guilds, counted per census point within the four stand conditions at the Terrace Hill study area and adjacent Coram Research Natural Area, Coram Experimental Forest, in 1989 and 1990

Guild[1]	Number of species	Stand condition: Clear-cut[2]	Partial-cut[2]	Unlogged forest	Natural area	Probability[3]
Foraging						
Foliage forager	23	2.4^{A}	5.0^{B}	4.5^{B}	4.7^{B}	0.001
Flycatcher	5	1.0^{A}	0.3^{B}	0.1^{B}	0.0^{B}	.001
Tree driller	4	0.7	0.5	0.5	0.9	.544
Tree gleaner	5	0.7^{A}	0.9^{AB}	1.3^{BC}	1.5^{C}	.003
Ground forager	14	3.4^{A}	2.7^{AB}	1.8^{BC}	1.4^{C}	.001
	51					
Nesting						
Conifer tree	8	1.0^{A}	2.6^{B}	2.5^{B}	2.7^{B}	.001
Conifer or broadleaf tree	10	1.4	2.0	1.6	1.8	1.000
Bush or small tree	10	1.5	1.6	1.2	1.0	1.000
Primary cavity	5	0.9	0.6	0.6	1.1	.416
Secondary cavity	9	1.6	1.0	1.3	1.6	1.000
Ground	9	1.7^{A}	1.5^{AB}	0.9^{BC}	0.3^{C}	.001
	51					

[1]Guilds adapted from Diem and Zeveloff (1980).

[2]Snags of all species and living paper birch left standing where possible.

[3]Low probability values indicate significantly different means among stand conditions, Bonferroni adjusted to control for experimentwise error; superscript letters group similar means for each guild (SPSS Inc. 1983).

Figure 1.3--Pine Siskins were more abundant in clearcut and partial-cut stands in 1990 compared to 1989, resulting in a significant interaction effect between stand conditions and years. Error bars show 95% confidence intervals for the mean number of birds detected per point.

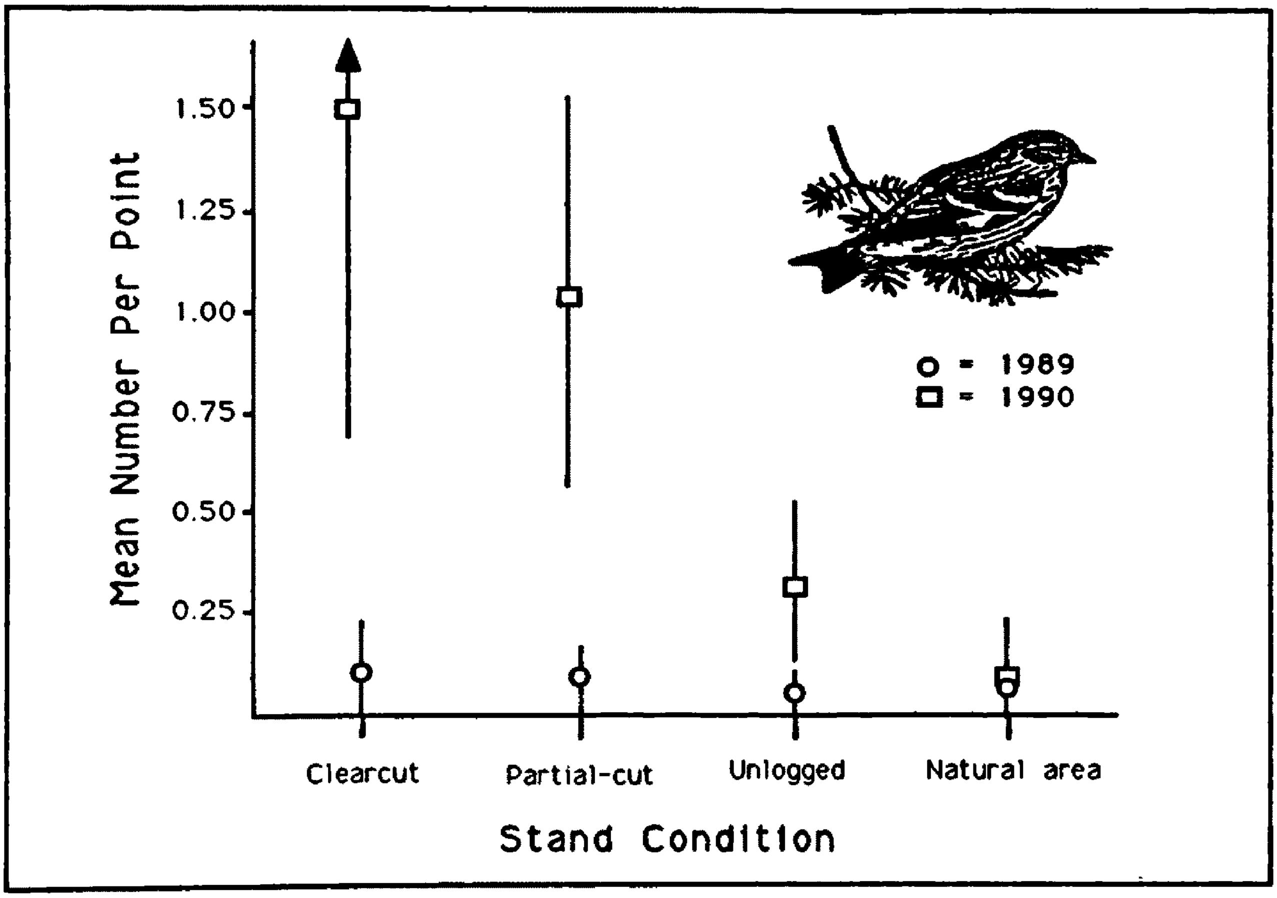
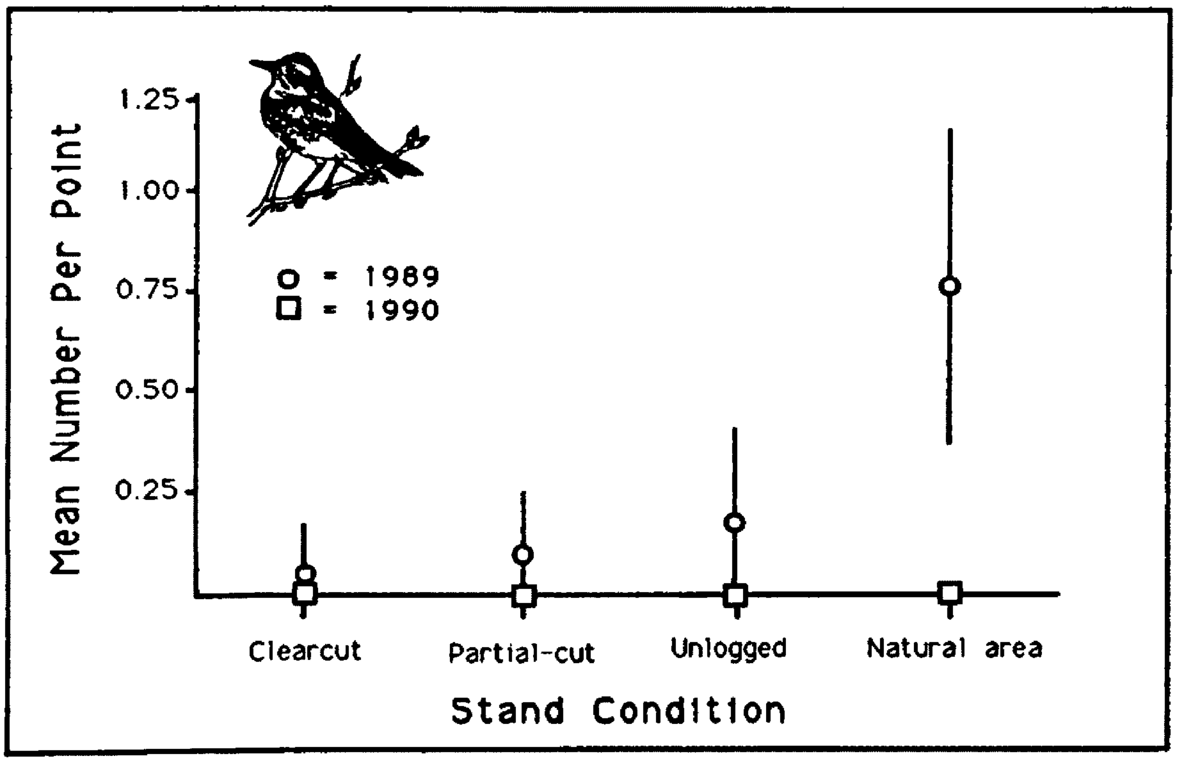


Figure 1.4--The abundance of Varied Thrush showed an interaction effect between stand conditions and years. During 1990, no Varied Thrush were detected while censusing, and they were relatively common in the natural area in 1989. Error bars show 95% confidence intervals for the mean number of birds detected per point.

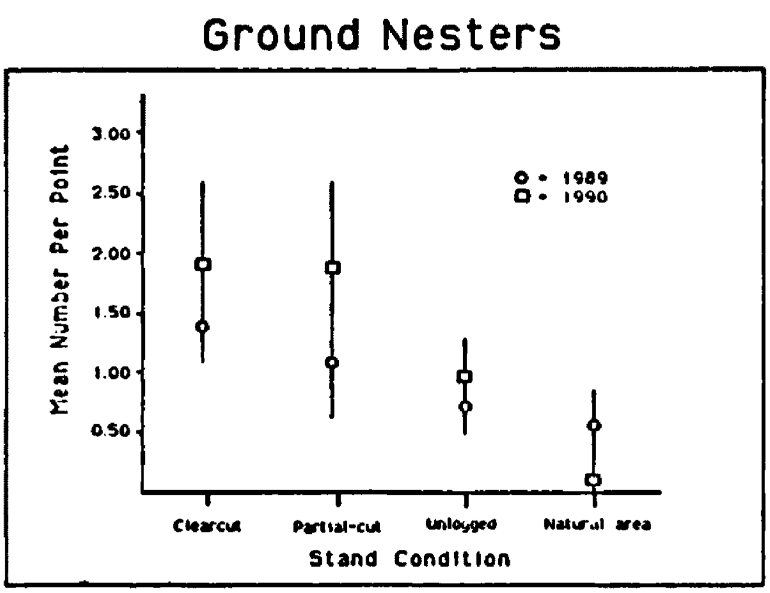


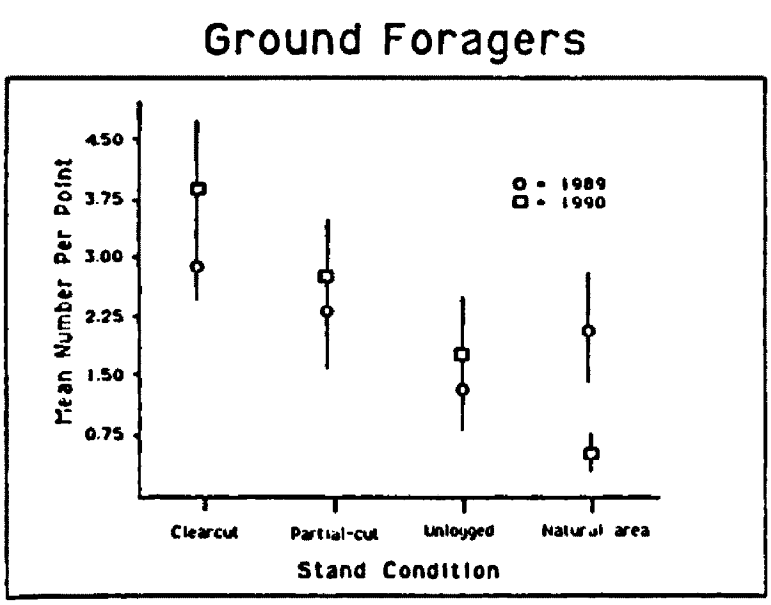
were Golden-crowned Kinglet, Swainson's Thrush, Varied Thrush, and Townsend's Warbler. Conversely, Dark-eyed Juncos and Pine Siskins were more abundant in harvested habitat than elsewhere. Ruby-crowned Kinglets and Fox Sparrows were least abundant in clearcuts and in the CRNA, while Chipping Sparrows were common in all areas except the CRNA.

Several other species did not exhibit significant differences in abundance, but were less abundant in clearcuts than elsewhere. These include Brown Creeper, Winter Wren, and MacGillivray's Warbler (table 1.2). Species that were more abundant in harvested stands but did not exhibit significant differences include Olive-sided Flycatcher, Townsend's Solitaire, and American Robin. Interestingly, robins were least abundant in the CRNA and relatively common in the unlogged forest between harvest units on the THSA.

When species were grouped into foraging guilds, following Diem and Zeveloff (1980), foliage foragers were least abundant in clearcuts. Similarly, tree gleaners were less abundant in clearcuts and partial cuts than in unharvested areas. In contrast, flycatchers and ground foragers were more abundant in harvested habitat, particularly clearcuts. Among the nesting guilds, conifer tree nesters were least abundant in clearcuts and ground nesters were most abundant in cutover sites. Ground nesters and ground foragers had a significant interaction effect between stand conditions and years because of an increase in abundance in harvested areas and a decrease in the undisturbed natural area (fig. 1.5).

Figure 1.5--Comparing 1990 to 1989, ground nesters and ground foragers were more abundant in clearcut, partial-cut, and unlogged forest, and less abundant in the natural area. The interactions between stand conditions and years may be evidence of site tenacity among the species in these guilds (see discussion). Error bars show 95% confidence intervals for the mean number of birds detected per census point.





DISCUSSION

For the bird species and guilds that exhibited significantly different numbers among stand conditions, patterns of abundance appear consistent with their habitat requirements. For example, Tree Swallows were most abundant in clearcuts where snags and birch trees were reserved (fig. 1.4). For these members of the flycatching and secondary-cavity nesting guilds, open, meadow-like habitat with nest-tree resources is probably ideal. Similarly, Dark-eyed Juncos, ground foragers and ground nesters, were most abundant in clearcuts and partial-cut units. In contrast, the members of the conifer tree nesting guild, species such as Golden-crowned Kinglet and Townsend's Warbler, were less abundant in clearcuts (tables 1.2 and 1.3).

Ruby-crowned Kinglets and Fox Sparrows were most abundant in partial-cut stands and unlogged forests interspersed between the cutting units. Perhaps an increase in edge habitat is beneficial to these species; males of both species were frequently heard singing from conifers adjacent to clearings. Chipping Sparrow and American Robin were least abundant in the CRNA and relatively abundant in the unlogged forest on the THSA, pointing out that they too may favor edge habitat in conjunction with open stands.

The abundance of Pine Siskin, a foliage-foraging and conifer- or broadleaf-tree nesting species showed a significant interaction between habitat and year (fig. 1.3). This was due to a dramatic increase in abundance during 1990 in clearcut and partial-cut stands. This species is known for sporadic, large changes in abundance and irruptive foraging behavior. Abundance of Pine Siskins within harvested habitat is the result of retaining living birch trees and the small size of the cutting units. These two factors may also have increased the abundance of other members of the conifer/broadleaf tree nesting guild (table 1.3).

The abundance of Varied Thrush also showed a significant habitat and year interaction (fig. 1.4). No varied Thrushes were detected while censusing during 1990 even though these birds were common within the natural area during 1989. Censusing during 1991 may help to clarify which year was unusual for this species on the study area. Varied Thrush is the only species among those that were most abundant in unharvested areas to have a significant difference in numbers between the unlogged forest and the natural area (table 1.2). This may illustrate a qualitative difference for this species between contiguous and fragmented old-growth forest.

Habitat and year interactions were also significant for ground-foraging and ground-nesting guilds (fig. 1.5). The number of ground foragers increased from 1989 to 1990 in clearcut, partial cut, and unlogged forest, but decreased in the CRNA. Numbers of ground nesters also increased more in partially cut areas than elsewhere. These patterns are shifts away from contiguous forest toward harvested and fragmented forest. A time-lag effect following logging, as described for these guilds, seems reasonable in light of the possibility of site tenacity by breeding birds (Atwood and Massey 1988). Adults may be predisposed to return to the same site to breed following migration, and they may not have time immediately upon arrival to search for other potential territories. If this is true, they may correct the situation in late summer when they have time to search for a new site. By the second year after treatment, an effect is evident.

Because more than half of the species included in the statistical analysis did not show significant differences in abundance among stand conditions, it is possible that factors related to logging may not affect the majority of species if reserving snags and live trees, and if small harvest units surrounded by unlogged forest function as mitigating influences. Other alternatives, however, merit consideration.

A factor that may have contributed to overlooking biologically important differences in abundance was the small sample consisting of 10 replicates within each stand condition. This reduced the power, or the ability to detect differences in means, for our statistical tests. The relative scarcity of many species contributed to this problem. Nineteen species were detected less than eight times during censusing; these were not included in the species-level analysis. Nonetheless, among the species included, zero counts at census points were commonplace, and this property of census data, in combination with the small sample size, served to inflate variance and render different sample means statistically indistinguishable.

An example of the conservative nature of our statistical tests is the Killdeer, which was detected only at two points in clearcut habitat during both years. As a ground-nesting and ground-foraging species, probably more Killdeer will use cleared than uncut habitat, but large variance (mean number counted per point in clearcuts = 0.15, standard error = 0.08) caused a failure to reject the null hypothesis of equal means. The power for this analysis of variance model was 44 percent, which was rather low. I grouped species into guilds (table 1.3) to partially circumvent the problem of uncommon species counts and, as shown in table 1.3, ground foragers and ground nesters showed a highly significant difference in abundance between habitats. They were especially common in clearcut and partially cut areas.

Even if population sizes do not vary among stand conditions, it is conceivable that the abundance of a species may not be a valid indicator of habitat suitability (Van Horne 1983). A given habitat may act as an ecological sink where individuals experience low reproductive success or high mortality in comparison to more favorable habitats (Wiens and Rotenberry 1981). For example, birds may be abundant in cleared areas but raise fewer offspring per nest than conspecifics in contiguous forest. The resupply of individuals to inadequate habitat from optimal areas could be behaviorally mediated.

Factors that ultimately determine habitat selection include food and cover availability, but Hilden (1965) suggested that vegetation structure is the proximate cue birds use to select territories. Birds arriving during spring in northern latitudes must select nesting territories based on structural features of the habitat rather than a direct assessment of food availability. If we manipulate habitat to provide appropriate cues for these species, we could see birds within the habitat even though it is not otherwise suitable. Thus, some human-altered environments may function as ecological sinks (Gates and Gysel 1978).

Consider woodpeckers, for example. We detected no difference in abundance between stand conditions for Red-naped Sapsuckers, Hairy

Woodpeckers, and Northern Flickers (table 1.2). A proximate cue that may influence a woodpecker settling into a nesting territory could be the previous year's nest tree, or simply the presence of a suitable snag. Lawrence (1967), studying Yellow-bellied Sapsuckers (*Sphyrapicus varius*) in Ontario, suggested that pair bonds were reestablished through site rather than mate recognition, and females in particular cued in on the former nest tree. Thus, by reserving snags and deciduous trees during the harvest and site preparation treatments on the THSA, adult woodpeckers returning in the spring may have been motivated to establish territories within inadequate habitat. A detailed study that evaluates habitat quality by estimating reproductive success among Red-naped Sapsuckers has been completed (Tobalske et al. 1990; see ch. 2.)

Wiens et al. (1986) suggested that interpretation of a species' response to habitat alteration may depend on the spatial scale of the manipulation. The largest clearcut on the THSA wa 14 ha (fig. 1.2), but commercial clearcuts may cover areas much larger (Dickson et al. 1983). Extrapolating the results of a small-scale study to that of a large-scale system is ignoring biological reality. Moreover, landscape-level changes on a very large scale, such as a portion of a state or country, may significantly affect bird species yet be impossible to address without regional data.

MANAGEMENT RECOMMENDATIONS

The variation in abundance within the community of breeding bird species relative to logged or unlogged stand conditions indicates that management for any particular species or guild will probably fail to provide for the integrity of the entire system. In short, diversity of habitat will likely promote diverse bird assemblages. During timber harvest, tree-dependent bird species are losing access to an important resource, and it is generally this portion of the bird community for which managers seek to mitigate adverse effects.

The most striking feature of the clearcuts on Terrace Hill is the large number of standing larch snags and live paper birch trees (fig. 1.4). It is feasible that the snags and living trees, along with the small size of the cutting units in relation to interspersed unlogged forest, mitigated the effect of the timber harvest for tree-dependent bird species, ranging from cavity nesters, such as Red-naped Sapsucker and Red-breasted Nuthatch, to foliage foragers, such as Yellow-rumped Warbler and Western Tanager. Therefore, I reiterate the recommendation of McClelland and Frissell (1975) to leave, wherever possible, all snags and nonmerchantable timber including paper birch, quaking aspen, and black cottonwood within cutting units.

Additionally, I observed a variety of species of birds, including Winter Wren, Townsend's Solitaire, and Dark-eyed Junco, using unburned slash piles as perches, food sources, or nest sites. These piles may contribute substantially to the quality of postharvest habitat for certain bird and small mammal species. Further study is required to establish the importance of this potential resource; nonetheless, measures should be taken to retain some slash piles during and after site treatments.

It is beyond the scope and intention of this study to provide quantitative recommendations regarding the optimum number of snags, trees, or slash piles to reserve when harvesting timber. Research in progress (Tobalske et al. 1990; see ch. 2) suggests that harvests that mimic naturally occurring habitat, such as an open, wooded meadow, may be the most appropriate models.

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APPENDIX 1: COMMON AND SCIENTIFIC NAMES OF BIRD SPECIES CENSUSED IN THIS STUDY

Red-tailed Hawk	Buteo jamaicensis
Ruffed Grouse	Bonasa umbellus
Killdeer	Charadrius vociferus
Barred Owl	Strix varia
Vaux's Swift	Chaetura vauxi
Rufous Hummingbird	Selasphorus rufus
Red-naped Sapsucker	Sphyrapicus nuchalis
Hairy Woodpecker	Picoides villosus
Three-toed Woodpecker	Picoides tridactylus
Northern Flicker	Colaptes auratus
Pileated Woodpecker	Dryocopus pileatus
Olive-sided Flycatcher	Contopus borealis
Western Wood-Pewee	Contopus sordidulus
Dusky/Hammond's Flycatcher	Empidonax spp.
Tree Swallow	Tachycineta bicolor
Gray Jay	Perisoreus canadensis
Steller's Jay	Cyanocitta stelleri
Clark's Nutcracker	Nucifraga columbiana
Common Raven	Corvus corax
Black-capped Chickadee	Parus atricapillus
Mountain Chickadee	Parus gambeli
Chestnut-backed Chickadee	Parus rufescens
Red-breasted Nuthatch	Sitta canadensis
Brown Creeper	Certhia americana
Winter Wren	Troglodytes troglodytes
Golden-crowned Kinglet	Regulus satrapa
Ruby-crowned Kinglet	Regulus calendula
Mountain Bluebird	Sialia currucoides
Townsend's Solitaire	Myadestes townsendi
Swainson's Thrush	Catharus ustulatus

(Con.)

APPENDIX (Con.)

American Robin	Turdus migratorius
Varied Thrush	Ixoreus naevius
Solitary Vireo	Vireo solitarius
Warbling Vireo	Vireo gilvus
Orange-crowned Warbler	Vermivora celata
Yellow Warbler	Dendroica petechia
Yellow-rumped Warbler	Dendroica coronata
Townsend's Warbler	Dendroica townsendi
American Redstart	Setophaga ruticilla
Northern Waterthrush	Seirus noveboracensis
MacGillivray's Warbler	Oporornis tolmiei
Wilson's Warbler	Wilsonia pusilla
Western Tanager	Piranga ludoviciana
Black-headed Grosbeak	Pheucticus melanocephalus
Chipping Sparrow	Spizella passerina
Fox Sparrow	Passerella iliaca
Dark-eyed Junco	Junco hyemalis
Brown-headed Cowbird	Molothrus ater
Northern Oriole	Icterus galbula
Cassin's Finch	Carpodacus casinii
Pine Siskin	Carduelis pinus

CHAPTER 2

EVALUATING HABITAT SUITABILITY WITH FLEDGING SUCCESS AMONG RED-NAPED SAPSUCKERS

INTRODUCTION

Extirpation of the Ivory-billed Woodpecker (Campephilus principalis) from the North American continent (Short 1982) is a painful reminder of the potential for conflict between the habitat needs of woodpeckers and human exploitation of forests for timber resources. Woodpeckers require trees of sufficient diameter and decay to permit nest excavation, and many species forage exclusively upon trees (Short 1982). To provide for cavity-nesting wildlife, forest management objectives on public lands generally require some level of snag (standing, dead tree) retention within cutting units (McClelland 1975, Bull et al. 1986). In fact, numerous studies show that some of the smaller species of woodpeckers will readily nest and forage in cutting units with snags left standing (McClelland and Frissell 1975, Connor et al. 1975, Franzreb and Ohmart, 1978, Dickson et al. 1983, Tobalske et al. 1991, see ch. 1).

Birds probably select habitat on the basis of structural cues (Hilden 1965, Renken and Wiggers 1989). Natural selection should favor the evolution of a settling response to proximate cues that reliably predict aspects of habitat suitability such as protection from predation and high food availability. This may be the case in natural systems, but Gates and Gysel (1978) found that structural cues in human-altered environments can motivate some species to nest in areas in which adult and nestling mortality is abnormally high. Wiens and Rotenberry (1981) argued that such habitat may function as "ecological sinks" which are resupplied with individuals by dispersal from higher-quality "source" habitats. Given the drastic alteration of forest structure due to logging, it is conceivable that the retention of snags could create ecological sinks within the range of a given species.

Snags reserved from cutting for cavity-nesting wildlife are often retained because of evidence that woodpeckers actually use those snags for the purposes of nesting or foraging (Tobalske et at. 1991; see ch. 1). However, use of such snags by adults may result primarily from nest site tenacity in which birds exhibit a tendency to return to breed each year within their former nesting territory. Evidence for site tenacity among woodpeckers is summarized by Ingold (1991) who observed stronger nest site tenacity among migratory Red-headed Woodpeckers (Melanerpes erythrocephalus) than resident Red-bellied Woodpeckers (M. carolinus). Red-naped Sapsuckers and Yellow-bellied Sapsuckers (Sphyrapicus varius), both migratory species, occasionally dig new nests in previously used nest trees (McClelland 1975, Kilham 1983, pers. obs.). Moreover, Lawrence (1967) noted that female Yellow-bellied Sapsuckers may cue upon their previous year's nest tree when settling into a territory.

In addition to nest site tenacity, woodpeckers may settle in logged habitat with some trees left standing because of perceived similarities to naturally occuring habitat. For example, recently clearcut stands with reserved paper birch (Betula papyrifera) appear similar to aspen (Populus spp.) meadows and riparian zones within which Red-naped

Sapsuckers are abundant (McClelland 1975, pers. obs.).

I became intrigued by the response of Red-naped Sapsuckers to timber harvesting while studying breeding-season bird populations in coniferous forest in northwestern Montana (Tobalske et al. 1991; see ch. 1). There was no difference in the abundance of sapsuckers relative to clearcut, partial-cut, and unlogged stand conditions (fig 2.1). In contrast, 11 other bird species exhibited significant differences in abundance among stand conditions. The logged stands had snags and living paper birch retained within them to provide for cavity nesters.

Along with excavating nests in trees, sapsuckers require trees for the construction of sapwells where they glean for insects and feed upon phloem and cambium (Foster and Tate 1966). It seemed incongruous that extensive overstory removal had no effect upon the abundance of Red-naped Sapsuckers. Because patterns of abundance do not necessarily reflect habitat quality (Van Horne 1983), a more thorough analysis should compare habitat characteristics with a component of fitness, such as reproductive success, in addition to measures of abundance. In the present study, I investigate the relationships between vegetation characteristics in home territories and the number of young fledged per nest among Red-naped Sapsuckers. I also evaluate whether logged habitat, with nesting trees available, is likely to act as an ecological sink for Red-naped Sapsuckers.

Figure 2.1--The mean number of Red-naped Sapsuckers detected per census point in logged and unlogged western larch/Douglas-fir forest during the 1989 and 1990 breeding seasons (Tobalske et al. 1991, see ch. 1). Standard error bars show 95% confidence intervals for the mean number of birds detected per point. Harvested units had snags of all tree species and living paper birch reserved. Unlogged stands were interspersed between logged areas and the Natural Area was a contiguous 339-ha stand.

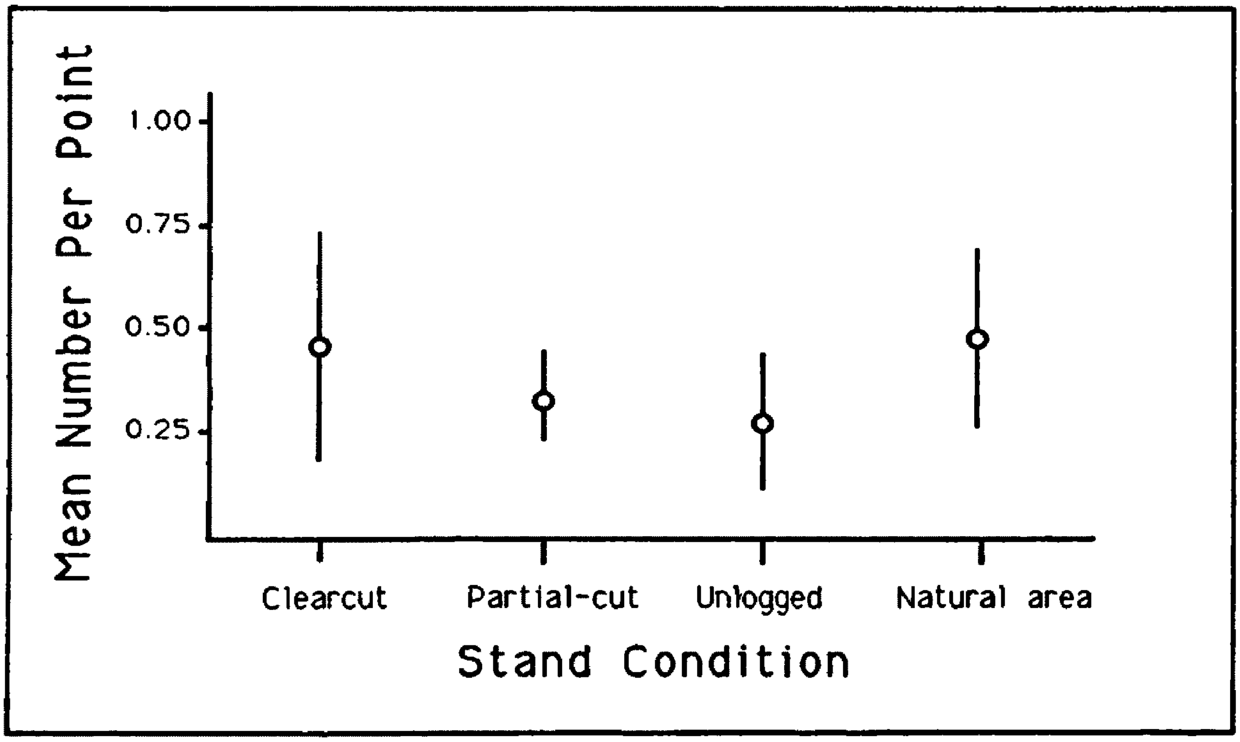
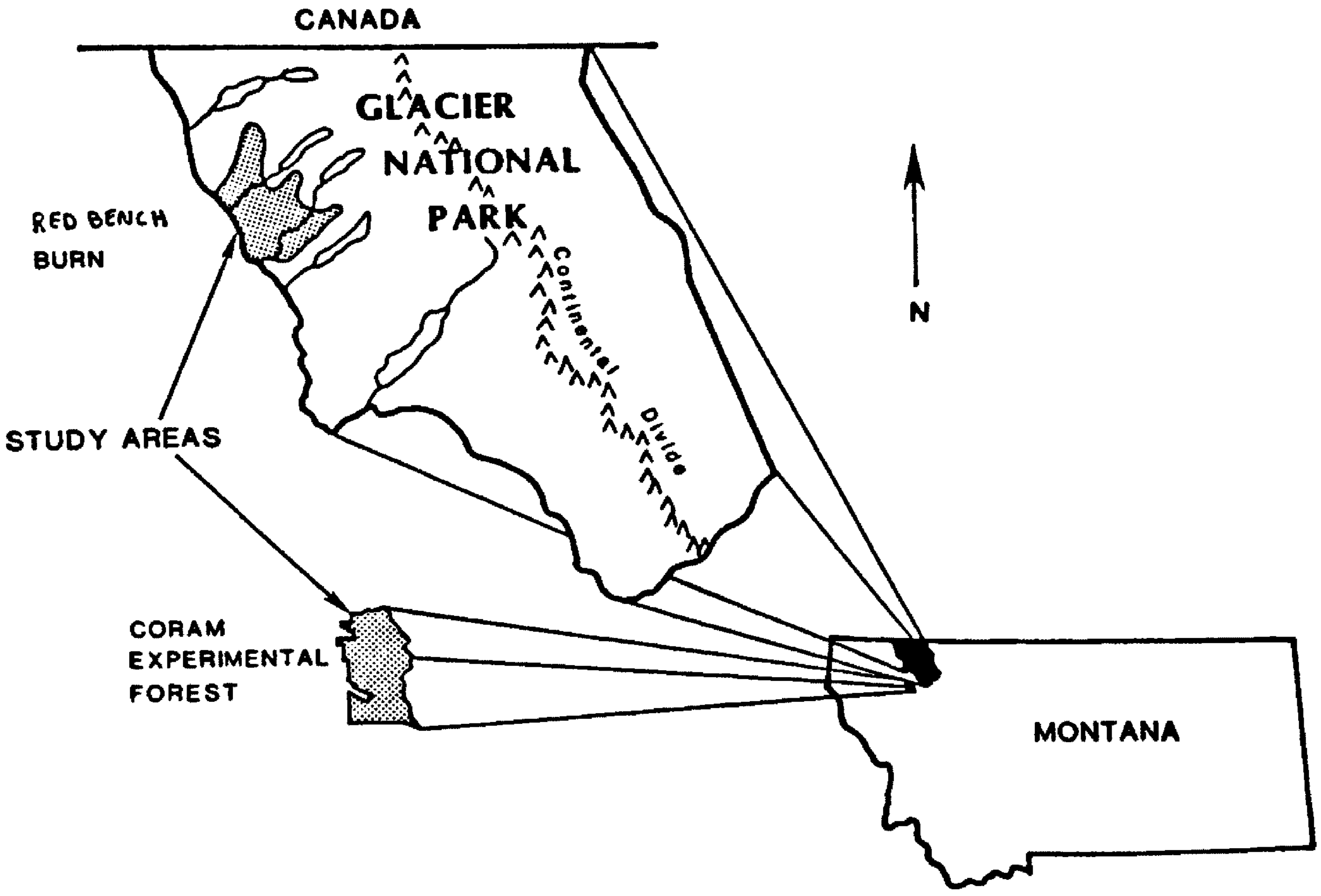


Figure 2.2--The study was conducted on Coram Experimental Forest, in the Flathead National Forest, and in the Red Bench Burn Area of Glacier National Park.



STUDY AREA

This study was conducted at two locations: Coram Expermental Forest, within the Flathead National Forest, Montana, and the Red Bench Burn Area within Glacier National Park, Montana (fig. 2.2).

Coram Experimental Forest (fig. 2.3) is a 3,000-ha field laboratory administered by the Intermountain Research Station of the U.S. Forest Service. Elevation ranges from 1,000-2,000 m. Western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) are the dominant trees on Coram, and Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) are common. At lower elevations, in association with riparian areas, paper birch, quaking aspen (*Populus tremuloides*), and black cottonwood (*P. trichocarpa*) are present. Unlogged stands are primarily even aged, and the old-growth larch is generally 300 years old. Timber harvesting began during the 1940's and continues today, using clearcutting and various partial-cutting methods (fig. 2.3). Since the mid 1970's, snags of all tree species, and living paper birch, quaking aspen, and black cottonwood have been retained within cutting units to manage for cavity-nesting wildlife based upon the guidelines summarized in McClelland and Frissell (1975).

The Red Bench Burn Area is adjacent to the North Fork of the Flathead River, in the western portion of Glacier National Park, managed by the U.S. National Park Service (fig 2.4). Naturally burned stands provided an alternative form of disturbance to compare with logged and unlogged coniferous forest. The forests within this area burned 6-16 September 1988, encompassing 9,500 ha. Elevation within the burned area

Figure 2.3--The location of Red-naped Sapsucker nests in relation to logged and unlogged stands on Coram Experimental Forest.

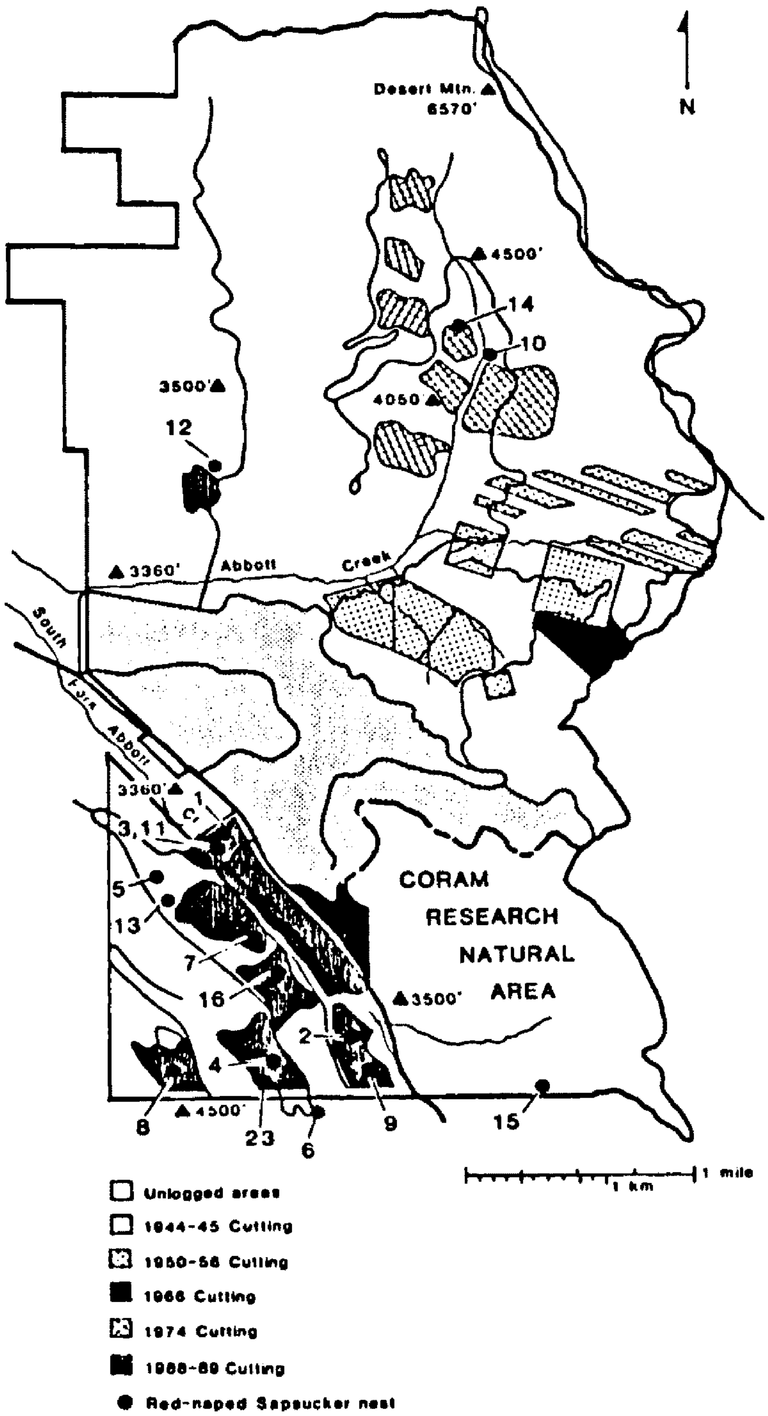
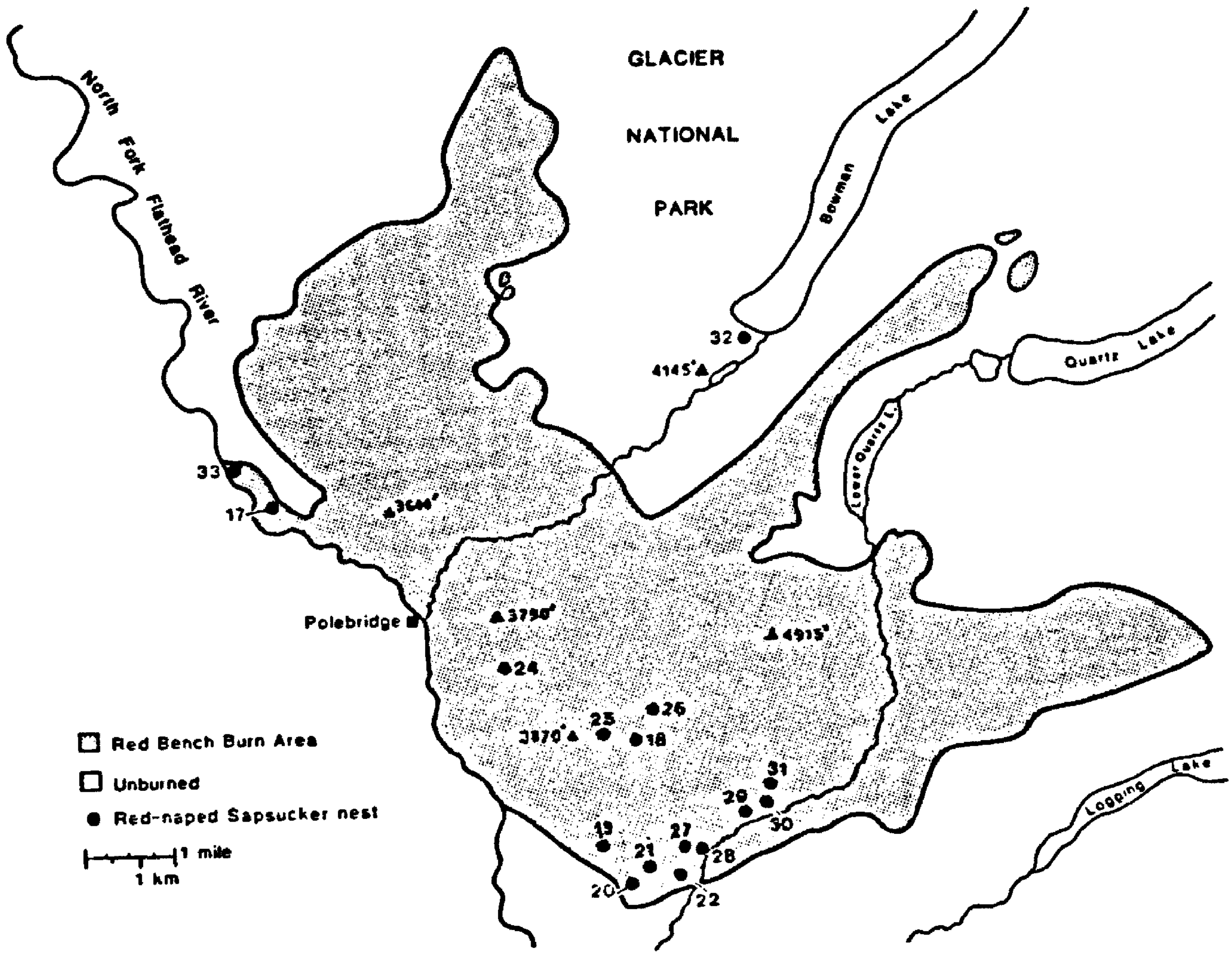


Figure 2.4--Location of Red-naped Sapsucker nests in the Red Bench Burn Area of Glacier National Park.



ranges from 1,100-1500 m. The dominant tree species (mostly snags within the fire boundary) is lodgepole pine (Pinus contorta). Other conifer species present include western larch, Douglas-fir, and ponderosa pine (Pinus ponderosa). Quaking aspen stands are found scattered throughout the area in meadows and riparian areas. Limited tree removal, associated with campgrounds, secondary roads, and trailshas occurred within this study area. One sapsucker nest included in the study was in unburned habitat adjacent to the burn area (nest 32, fig 2.4).

METHODS

Red-naped Sapsucker nests were located and monitored during the 1989 and 1990 breeding seasons, between 20 April and 1 August of each year. Care was extended at all times to minimize disturbance to the birds. During 1989, I located nests within Coram Experimental Forest (fig 2.3) by following adult birds or by tracking down the persistent vocalizations of nestlings. The adults were most active, and the juveniles most vocal, during the two weeks prior to fledging of the young. Most of the nests were discovered during this period.

During 1990, one full-time field assistant helped search for nests within Coram, using the same methods as in 1989. In addition, several researchers in the National Park Service, incidental to their own work, would notified me when they encountered active sapsucker nests in the Red Bench Burn Area (fig. 2.4). This was the only effort applied toward searching for nests within the park.

Estimates of reproductive success were obtained during the 1990 breeding season only. All nests were monitored until the young fledged. After locating a nest, I climbed the nest tree at irregular intervals, up to one week apart, to observe nests and nestlings. Section ladders, chain-steps, or logger's spikes were used to climb the nest trees. For viewing nest contents, I used a battery-charged light bulb suspended from the end of a dental mirror.

Vegetation was sampled within the home territory of each nesting pair. I adopted Lawrence's definition of a home territory as the defended portion of the home range, which was generally within 30 m of the nest tree for Yellow-bellied Sapsuckers (Lawrence 1967). Using survey flagging, I marked a circle with a 30-m radius around the nest tree, and divided the circle into quadrants with markers running north, south, east and west. Habitat variables measured were similar to those sampled by Renken and Wiggers (1989) who studied Pileated Woodpeckers.

Two vegetation variables were mean values calculated from measurements taken in each of four quadrants within the territories (table 2.1). Tree basal area was estimated with a "Relascope" prism while standing at the center of each of the quadrants, and I estimated the height of the overstory with a clinometer.

Other variables were total counts, in which trees of all species, including the nest tree, were tallied (table 2.1). These include trees 10-30 cm dbh, trees > 30 cm dbh or larger, snags 10-30 cm dbh, and snags > 30 cm dbh. Additionally, I counted live trees and snags of paper birch and aspen because Red-naped Sapsuckers showed some preference for

Table 2.1--Means, standard errors and ranges of vegetation variables measured in home territories of Red-naped Sapsuckers (n = 33).

Characteristic	Mean	SE	Range
Basal area (m^2/ha)	7.1	0.4	0.4-18
Overstory canopy height (m)	20.5	1.5	9-48
Trees 10-30 cm dbh	52.5	10.1	0-164
Trees > 30 cm dbh	14.0	3.1	0-70
Snags 10-30 cm dbh	25.2	4.0	0-76
Snags > 30 cm dbh	7.7	1.4	0-34
Birch and aspen 10-30 cm dbh	18.3	3.8	0-86
Birch and aspen > 30 cm dbh	6.4	1.1	0-23
Overstory canopy cover (%)	24.3	3.6	1-71
Percent of territory undisturbed	32.6	5.6	0-99
Percent of territory logged	31.7	6.6	0-99
Percent of territory burned	35.4	7.4	0-99

foraging and nesting in these two species (McClelland 1975, Crockett and Hadow 1975, pers. obs.).

Overstory canopy cover was the ground-level estimate of an imaginary vertical projection of the tree canopy, including branches and leaves. Lastly, I estimated the percentage of ground within the territory covered by undisturbed, logged, and burned habitat (table 2.1).

All variables were approximately normally distributed, and parametric methods were therefore employed for all statistical tests. Statistical significance was considered to be $P \leq 0.05$, although I report all correlations where $P \leq 0.15$. I compared the mean number of young fledged per nest within cutting units to the mean within adjacent unlogged areas of Coram Experimental Forest. I then added nests within the Red Bench Burn Area to the sample to test the relationships between the number of young fledged per nest and the vegetation variables sampled in the home territories. I employed Pearson's correlations (SPSS Inc. 1983), and I incorporated the statistically significant ($P \leq 0.05$) correlates into regression equations to predict the number of young fledged.

RESULTS

Thirty-three Red-naped Sapsucker nests and home territories were studied: 17 were in Coram Experimental Forest and 16 in Glacier National Park (table 2.1). Twenty-nine of the nests were in paper birch

Table 2.2--Pearson's correlation values of the number of Red-naped Sapsucker young fledged per nest with vegetation characteristics in the home territories (n = 24). Comparisons included if $P \leq 0.15$.

Variable Compared	Correlation	Probability
Percent of territory logged	0.51	0.011
Birch or aspen 10-30 cm dbh	0.31	0.146
Birch or aspen > 30 cm dbh	-0.45	0.028
Canopy height	-0.37	0.079
Snags > 30 cm dbh	-0.33	0.118
Percent of territory burned	-0.33	0.116

or aspen, three in western larch, and one in Douglas-fir. For details on the characteristics of nest cavities and nest trees see appendices 2.1-2.2.

Fledging data were collected for 24 of the sapsucker nests during 1990. Nine of these nests were in Coram Experimental Forest, and fifteen were in the Red Bench Burn Area (figs. 2.3-2.4). Evidence of predation upon adults or nestlings weas not detected. At least one juvenile fledged from each nest, although unhatched eggs and dead nestlings were found in some nests. On average, 3.33 youngfledged per nest (range 1-6). The mean number of young fledged per nest within cutting units on Coram Experimental Forest was higher (mean = 4.20, n = 5) than the mean observed in adjacent, unlogged areas (mean = 3.25, n = 4), although the difference lacked statistical significance. The number of birch and aspen 10-30 cm dbh and the percentage of logged habitat in the home territory were both positively correlated with the number of young fledged per nest (table 2.2). In contrast, four variables were negatively correlated with the number fledged: number of snags > 30 cm dbh, number of birch and aspen > 30 cm dbh, mean canopy height, and percentage of burned habitat in the home territory.

The percentage of logged habitat in the home territory and the number of birch or aspen > 30 cm dbh were the only statistically significant correlates (fig 2.5). A regression model incorporating both of these variables accounted for 37% of the variation in the number of young fledged per nest (table 2.3). Another regression model, using

Table 2.3--Regression equations predicting number of young fledged as a function of A) percent of territory logged and number of birch and aspen > 30 cm dbh, and B) percent of territory logged and number of birch and aspen 10-30 cm dbh.

A) N Fledge = 2.94 + 0.02(percent logged) - 0.06(big birch and aspen)

$R^2 = 0.37$, $P = 0.007$

B) N Fledge = 2.79 + 0.02(percent logged) + 0.01(small birch and aspen)

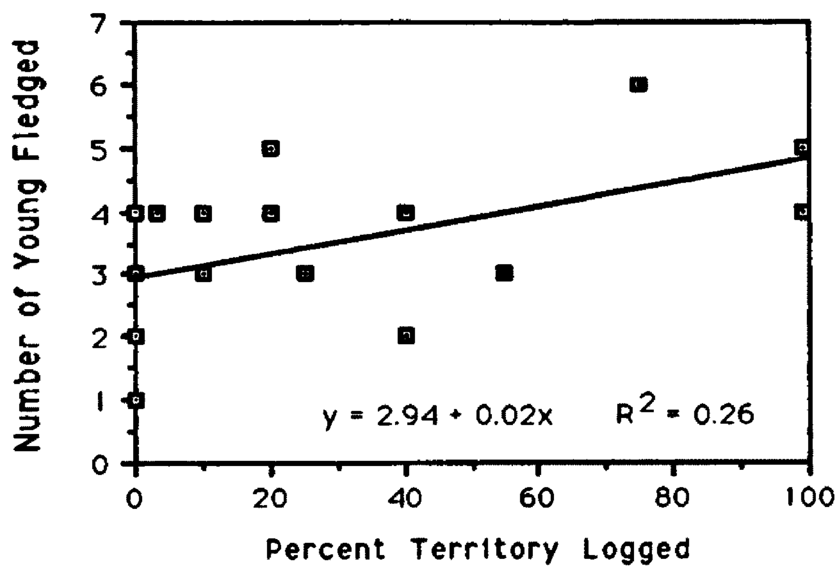
$R^2 = 0.30$, $P = 0.022$

Table 2.4--Pearson's correlations and probability values for comparisons between vegetation characteristics within Red-naped Sapsucker home territories. Comparisons included if $P \leq 0.15$

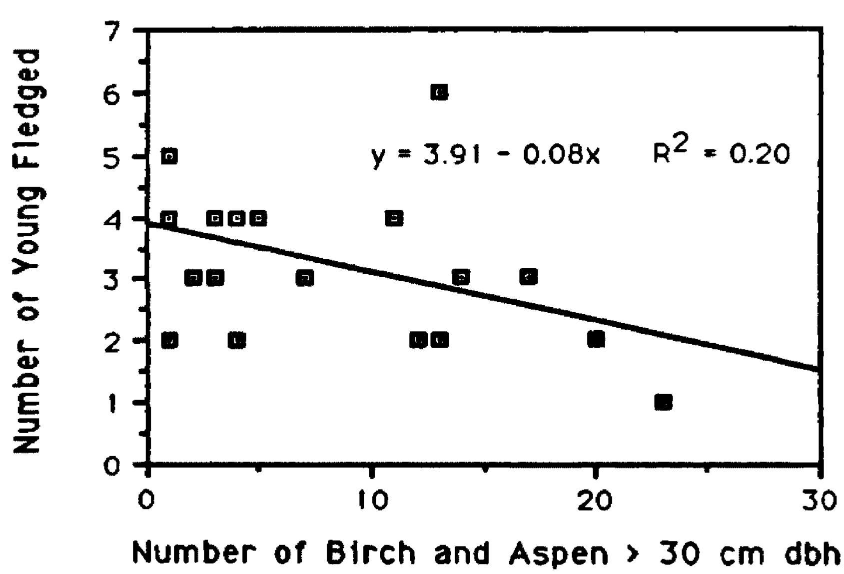
	Percent Logged	Birch, Aspen 10-30 cm dbh	Birch, Aspen > 30 cm dbh	Canopy Height	Percent Burned	Snags > 30 cm dbh
Percent Logged	1					
Birch, Aspen 10-30 cm dbh	—	1				
Birch, Aspen > 30 cm dbh	-0.32 (0.06)	0.28 (0.11)	1			
Canopy Height	-0.44 (0.01)	—	0.29 (0.10)	1		
Percent Burned	-0.69 (0.00)	-0.44 (0.01)	0.81 (0.00)	—	1	
Snags > 30 cm dbh	-0.66 (0.00)	-0.33 (0.06)	0.37 (0.03)	—	—	1

Figure 2.5--Two vegetation variables were significantly correlated with the number of Red-naped Sapsucker young fledged. Percent of territory logged was positively correlated (A), and number of birch and aspen > 30 cm dbh was negatively correlated (B)

A



B



percent logged habitat and number of birch and aspen 10-30 cm dbh accounted for only 29% of the variation in number fledged (table 2.3), but may be more useful to forest managers retaining trees from logging.

Intercorrelations were evident among the vegetation variables that were correlated with the number of young fledged (table 2.4). Logged habitat was positively correlated with the number of birch and aspen 10 - 30 cm dbh, reflecting the manner of timber harvesting on CoramExperimental Forest. There was a negative correlation between percent logged habitat and percent burned habitat, canopy height, number of snags > 30 cm dbh, and number of birch and aspen > 30 cm dbh.

DISCUSSION

Habitat characteristics within home territories may influence reproductive success among birds by altering predation pressure (Martin and Roper 1988), food availability (Martin 1987), or the thermal environment to which adults and nestlings are exposed (Walsberg 1981). My data do not permit an estimate of the relative contribution of each of these factors to fledging success among Red-naped Sapsuckers, but several vegetation variables sampled within the home territories were correlated with the number of young fledged per nest. The manner in which sapsuckers use these variables suggests that food availability was a primary determinant of fledging success. Correlations do not necessarily identify causal relationships though, and this is important to keep in mind when interpreting my results.

The percent of logged habitat in the home territory and the number of birch and aspen 10-30 cm dbh were positively correlated with the number of young fledged per nest (table 2.2). Red-naped Sapsuckers nesting in or near small clearcuts with living paper birch trees left standing generally fledged five or six young in comparison to an overall mean of 3.33 per nest. For nesting then, this type of home territory was apparently high quality.

Perhaps the proximity of live birch and aspen trees and logging slash increased access to food for sapsuckers nesting in harvested areas. Birch trees are the preferred source of phloem during the summer for Yellow-bellied Sapsuckers; the sap from these trees is higher in sugar content than that of conifers and other broadleaf species (Tate 1973). Red-naped Sapsuckers use both paper birch and aspen regularly. Smaller trees, less than 30 cm dbh, tend to have thinner bark which is also preferred (Tate 1973). Beal (1911) analyzed the stomach contents sapsuckers and found mid-summer diets consisted largely of ants (Hymenoptera) and beetles (Coleoptera). Sapsuckers typically glean for insects at sapwells, on the trunks of other trees, or on the ground (Tate 1973), and they will hawk flying insects (Lawrence 1967, pers. obs.). In territories that were heavily logged, both ground foraging and hawking behavior may have been facilitated by open conditions and abundant logging slash.

Apparently, the benefits associated with nesting in logged stands with paper birch and aspen reserved did not extend to burned forest. The variables that were negatively correlated with the number of young fledged (table 2.2) generally described habitat conditions surrounding many of the nests within the Red Bench Burn Area of Glacier National Park. Most of the deciduous trees within the burn were large (greater than 30 cm dbh) aspens killed by the fire, so they were not used for sapwells. However, open conditions, snags, and considerable levels of downed wood should have provided substrate for foraging. Other woodpecker species, including Northern Flickers (Colaptes auratus), Hairy Woodpeckers (Picoides villosus), and Three-toed Woodpeckers (Picoides tridactylus) were relatively abundant within the Red Bench Burn Area. These species may have competed with sapsuckers for insects on snags and downed wood and thereby decreased food availability. The paucity of suitable sapwell trees within the burn area could have intensified such competition.

As the mean number of young fledged per nest was not significantly different between cut and adjacent unlogged areas on Coram Experimental Forest, it appears that forest management guidelines that require snag and paper birch or aspen retention within cutting units are not likely to create ecological sinks for Red-naped Sapsuckers. The positive correlations observed between percent of territory logged, number ofbirch and aspen 10-30 cm dbh, and fledging success seem to support this argument. Moreover, judging from fledging success, the abundance of Red-naped Sapsuckers within extensively logged stands was not a misleading indicator of habitat quality (fig 2.1). This is an encouraging observation, for many studies rely upon census data alone to infer habitat suitability (e.g. Austin and Perry 1979, Szaro and Balda 1979, Medin 1985, Verner and Larson 1989, Tobalske et al. 1991, see ch. 1).

These conclusions are somewhat limited by the spatial and temporal scale of my investigation. Most of the cutting units on Coram Experimental Forest were smaller than 16 ha, and adult sapsuckers foraged much further from the nest than the 30-m radius that I selected to define home territories. Thus, they were exposed to conditions that I did not quantify. Without banding or telemetry data, I was unable to delineate home ranges (see Renken and Wiggers 1989), and it is possible that the total foraging range for any pair was 10 ha or more (Lawrence 1967, McClelland 1975). Certainly, the unlogged coniferous forest surrounding the cutting units was essential to the suitability of logged areas. For example, sapsuckers rely almost entirely upon conifer sap as a food source when they arrive in northern latitudes following spring migration (Tate 1973, McClelland 1975, pers. obs.). The sap in deciduous trees is stored in the roots until the leaves begin to bud, and insects are not abundant until later in the season.

It is also important to keep in mind that fledging success is but one indicator of reproductive success for adult birds during the breeding season. Sullivan (1989) reported that the highest rates of mortality among Yellow-eyed Juncos (Junco phaeonotus) occurred during the juvenile stage of the life cycle, when young were newly independent of adults. Sapsuckers are able to forage on their own soon after they leave the nest (Crockett and Hansley 1977, pers. obs.); moreover, the adults and young disperse from their home territory soon after the nest is evacuated. Predation pressure may be much greater after juveniles leave the comparative safety of the nest, and different vegetation characteristics that are related to survival during this time may not be the same as those that are correlated with fledging success.

This study was conducted during a single breeding season, so I am unable to infer long-term patterns of habitat suitability for Red-naped Sapsuckers. It is quite likely that habitat quality for birds varies among years (Wiens and Rotenberry 1981), and patterns evident in any one year may therefore change over time. Koenig and Mumme (1989) have studied Acorn Woodpecker (Melanerpes formicivorous) population demographics for well over a decade and have observed particularly low recruitment only in years following acorn crop failure. Connor and Crawford (1974) found Hairy and Downy Woodpeckers foraged extensively in year-old clearcuts, but these species used five- and twelve-year-old cuts much less. In contrast, Northern Flickers foraged in the five-year-old cut more than the other stands. The differences in habitat use were unique to each bird species, and appeared to be associated with changes in food availability and vegetation structure following ecological succession.

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APPENDIX 2.1: A NEGATIVE CORRELATION BETWEEN NEST DEPTH AND NUMBER OF YOUNG FLEDGED AMONG RED-NAPED SAPSUCKERS

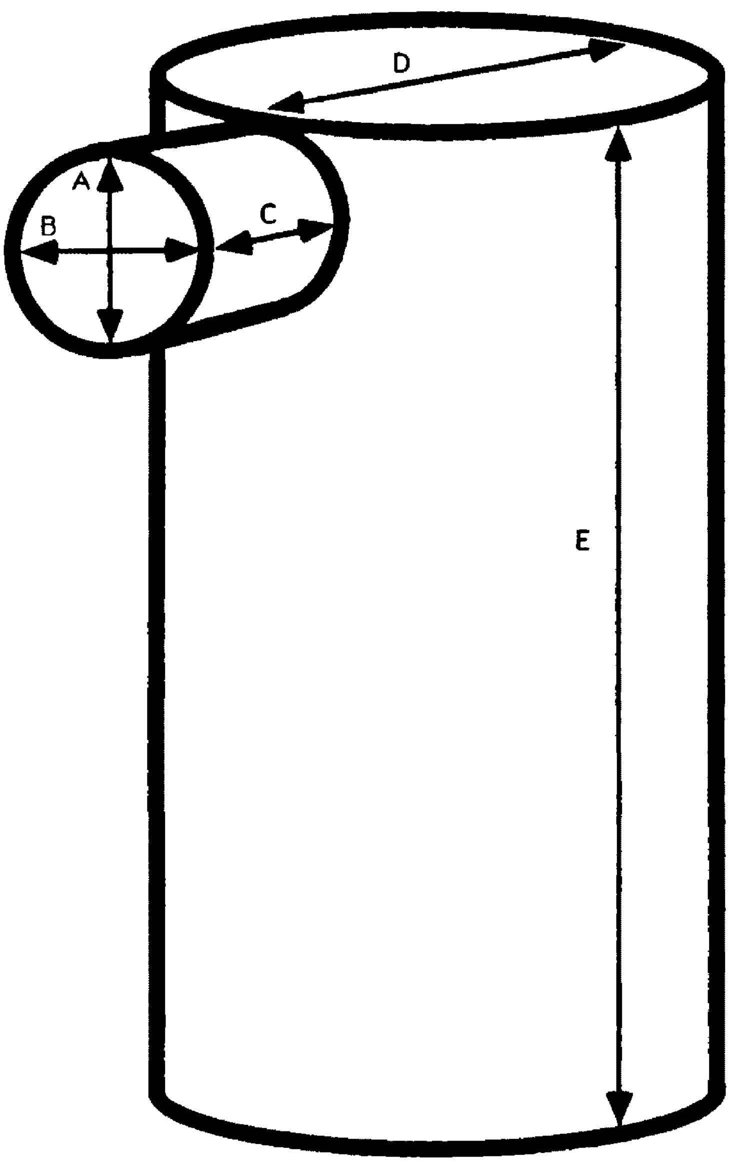
Data on the characteristics of Red-naped Sapsucker nest trees and nest cavities are available from a variety of sources including field guides (Harrison 1979). I collected data on nest cavities while monitoring nestlings during this study (table 1). The location on each nest where measurements were made is shown in fig. 1. In addition, I measured nest height and nest tree height (table 1).

I measured the depth of the nests with a flexible wire; the other cavity dimensions were measured with a metric ruler. Diameter of the tree at breast height and diameter at nest height were measured with a diameter tape. Nest height and nest tree height were estimated with a clinometer.

While monitoring the nests, I noticed that there appeared to be a negative relationship between the number of young fledged and the depth of the nest. The Pearson's correlation value between these two variables was -0.43 ($n = 24$, $P = 0.036$). In contrast, correlations between the number of young fledged and nest diameter or nest volume were not significant. The regression equation predicting number of young fledged as a function of nest depth was $Y = 7.29 - 0.16X$.

Further study is required to elucidate the processes contributing to this pattern. I suggest two possibilities here. There may be a constraint upon fledging success caused by levels of carbon dioxide or ammonia in the nest cavity. Howe et al. (1986) suggested that CO_2 levels in Nothern Flicker nests were moderated by convective transfer of air to the atmosphere outside the nest. These conditions may vary with nest depth. Another explanation may be competition for food among siblings is intensified in deeper nests. Some nestlings may be more successful at climbing to the nest entrance to recieve food from adults, causing starvation among their nest mates.

Figure 1--Location on nests where measurements were taken.



A = Entrance height, B = Entrance width, C = Ledge length,
D = Nest diameter, E = Nest depth.

Table 1--Means, standard errors, and ranges of variables associated with nest cavities and nest trees.

Characteristic	Mean	SE	Range	N
Entrance height (cm)	4.6	0.2	3.3-7.3	26
Entrance width (cm)	4.1	0.1	3.7-4.8	26
Ledge length (cm)	5.0	0.2	3.0-7.3	26
Nest diameter (cm)	7.9	0.6	4.8-10.2	26
Depth (cm)	25.2	85.6	21.6-33.0	26
Volume (cm^3)	1356.1	2.8	580.6-2304.3	26
Tree dbh (cm)	44.0	1.3	19.6-113.5	33
Tree dnh (cm)	30.3	0.3	19.6-57.2	33
Nest height (m)	11.7	1.6	1.1-45.3	33
Tree height (m)	20.9	1.8	4.7-48.0	33

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APPENDIX 2.2--ORIENTATION OF NEST ENTRANCES AND VERTICAL LEAN OF NEST TREES.

I recorded the entrance orientation and direction of tree lean near the nest for the 33 Red-naped Sapsucker nests observed in my study of reproductive success (fig. 1). I employed Rayleigh's test for non-random circular distribution (Batchelet 1981) to examine the data. Nest entrances appeared randomly distributed (table 1), but nest trees exhibited a significant tendency to lean to the west. I did not examine available unused trees; thus I am unable to assess whether the non-random distribution reflects preference among sapsuckers or the general condition of available nest trees within my study area.

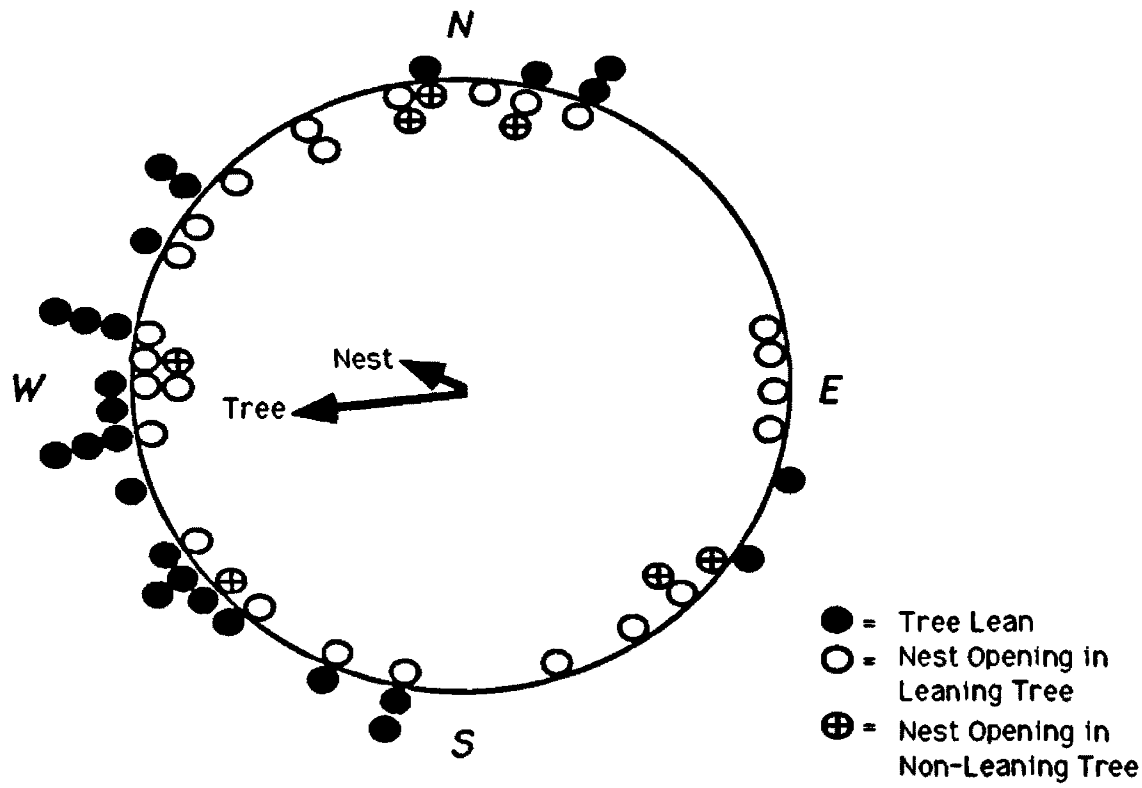
Table 1--Means and standard deviations for direction of nest entrance and lean of nest tree near nest. R is the length of a vector which is inversely proportional to dispersion of data about the mean. Low probability values indicate a significant nonrandom distribution using Rayleigh's test (Batchelet 1981).

Variable	Mean	S.D.	R	Probability
Nest entrance	293.7°	72.0°	0.2	0.268
Direction of lean	263.3°	56.98°	0.5	0.001

REFERENCE

Batchelet, E. 1981. Circular statistics in biology. Academic Press, London. 371p.

Figure 1--Orientations of Red-naped Sapsucker nest openings and direction of lean for the nest trees. The length of the vectors is inversely proportional to dispersion of data about the mean (Batchelet 1981).



APPENDIX 2.3--ADULT ACTIVITY NEAR THE NEST TREE

Table 1--Means and standard errors of attributes of adult Red-naped Sapsucker time budgets showing differences between sexes (n=24). Observations were made during the week prior to fledging of the young, for one hour at each nest.

	Male		Female		
Attribute	Mean	SE	Mean	SE	P[1]
No. perches near nest	7.96	1.04	4.00	0.63	0.000
Mean perch time (min)	0.41	0.07	0.36	0.08	0.679
No. feedings	9.29	0.81	6.58	0.74	0.001
Mean feeding duration	0.14	0.01	0.13	0.01	0.794
No. feces removal trips	0.88	0.34	0.21	0.10	0.046
No. flycatching sallies	1.58	0.80	0.25	0.14	0.103

[1] Probability of statistically significant difference between means using a paired t-test (SPSS Inc. 1983).