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Final Report

Bats of the northern Skagit watershed
Year 2000 Final Report

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INTRODUCTION

The majority of British Columbia's bat species are associated with forest habitats and are important contributors to these ecosystems. As major predators of nocturnal flying insects, bats may play a key role in the regulation of insect populations. Bats must consume great quantities of prey to satisfy high energy-demands (Barclay et al. 1991). Bats also contribute to the process of nutrient recycling because their foraging habitats are often different from their roosting habitats (where they deposit their nitrogen-rich feces). Rainey et al. (1992) found that bats play a significant local role in upslope nutrient transport. The extent of this contribution is still poorly understood in temperate zone ecosystems, and studies of bat habitat use may further clarify these relationships.

Spatial complexity (clutter) negatively affects foraging activity of certain bat species (Brigham et al., 1997). The amount of clutter in forests varies with forest age and structure. Young forests are often dense and homogeneous, thus presenting high amounts of clutter to bats. Previous studies have shown that bat activity in young stands is minimal (Crampton and Barclay 1996) or absent (Erickson and West 1996), probably due to high amounts of clutter combined with a lack of suitable roosts. Older forests are often more open, with heterogeneous structural complexity. Thomas (1988) found higher bat activity in old growth forests than in young or mature stands. This activity represented commuting as opposed to foraging, suggesting that bats are travelling to and from roosting habitat in these old growth forests. Elevation is another factor affecting bat habitat use. Bat abundance and activity, particularly of larger species, decreased with increased elevation (Kellner 1999). Different members of bat populations, depending on their individual life-history strategies and thermoregulatory constraints, may use certain elevations. For example, a recent study by Cryan et al. (2000) found higher numbers of reproductive female bats at low elevations, while males and non-reproductive females inhabited higher elevations. Understanding how bats use different habitat types and elevations is crucial in ensuring that their needs are considered in British Columbia's forest and land management plans.

The northern Skagit watershed, is an area of unique transition between coastal and interior ecosystems. Little is known about the diversity, abundance and habitat requirements of bats within the area. Twelve species of bats are potentially found within the area, four of which are on the B.C. Ministry of Environment Provincial Red and Blue lists as endangered or threatened (Table 1). A portion of the northern Skagit watershed falls within Skagit Valley

Provincial Park. The remainder falls mostly within Manning Provincial Park, Cascade Recreation Area and International Forest Product's (Interfor's) operating area.

The majority of the northern Skagit watershed consists of four main biogeoclimatic subzones: Interior Douglas-fir wet warm (IDFww), Coastal Western Hemlock southern moist submaritime variant (CWHms1), Mountain Hemlock moist maritime variant (MHmm2) and Engelmann Spruce-subalpine fir moist warm (ESSFmw). Biogeoclimatic ecosystem classification (BEC), developed by V.J. Krajina in the 1950's, integrates climate, soil and vegetation data to classify the various ecosystems of British Columbia (Meidinger and Pojar 1991).

Within the IDFww and CWHms1 zones, I have chosen to separate black cottonwood *(Populus balsamifera ssp. trichocarpa)* stands into their own " ecosystem zone" (Ac) because of their high habitat value for many wildlife species (Voller 1998). Black cottonwood is commonly associated with riparian areas and disturbed uplands at low to mid-elevations and it withstands periodic flooding and resists frost. Besides being an important stabilizer of riverbanks, shade from black cottonwood trees keeps water temperatures low and decaying leaves provide a rich source of nutrients for several types of insects including caddis flies (Trichoptera) and mayflies (Ephemeroptera; Parish et al., 1996).

The main objectives of this study were to identify bat diversity and distribution in the northern Skagit watershed and compare bat activity levels between forests of different ecosystem zones and ages. The results of this work will increase understanding of bat habitat use in terms of specific forest attributes, and can be incorporated into forest and land management plans to ensure that bats remain an integral part of forest ecosystems.

MATERIALS AND METHODS

Study Area

The northern Skagit watershed includes Skagit Valley Provincial Park (49°06' N, 121°09' W) and portions of EC Manning Provincial Park (49°06' N, 120°44' W), the Cascade Recreation Area (49°17' N, 120°57' W) and part of International Forest Product's operating area (Figure 1, map created and supplied by Keystone Wildlife Research). The elevation of the study area ranges from 500 m to 1650 m above sea level. Climate in the area is variable depending on the biogeoclimatic zone (Hamilton et al. 1999). Due to limited access and low availability of intact forests, the MHmm2 zone was not included in the study. The climatic characteristics of the four main ecosystem zones included in this study are listed in Table 2.

Study Design

Fieldwork was conducted during the period of peak bat activity, from mid-May to mid-August, 2000. Within each of the four ecosystem zones, I separated forests into three different age groups (young, medium and old). The age distribution of these age groups is summarized in Table 3. Black cottonwood is a fast-growing species that rarely exceeds 200 years old (Parish et al., 1996); therefore, the classification of young, medium and old forests for this zone differ from the other ecosystem zones in the study (Table 3). In total, there were 12 habitat types sampled (4 zones x 3 age groups).

Stands (identified as forest-cover polygons) were chosen from forest-cover and terrestrial ecosystem maps based on age class, stand size, structural stage, species composition and accessibility. Chosen stands consisted predominantly of climax tree species for their particular zone. I sampled individual polygons (to increase sampling across the landscape); however, exceptions to this were made when there was a low availability of certain stand types (such as within Ac). In these cases, sites were located at least 50 m away from the previous site to ensure some independence of sampling.

Capture, Identification and Reference Calls of Bats

To determine the species and reproductive status of bats in the study area, I captured bats using mistnets placed over potential foraging and drinking areas or along flyways used by commuting bats (e.g. roads and trails). Netting began at dusk and continued for at least two hours. Nets were checked every ten minutes, and captured bats were removed and held in cloth bags for one hour to ensure passage of feces so that an accurate mass could be measured. I recorded the following: species, sex, age, reproductive condition, mass and forearm length. Bats were classified as juvenile or adult depending on the degree of epiphyseal-diaphyseal fusion in the fourth metacarpal (Anthony 1988). Reproductive condition of female and male bats was determined as outlined by Racey (1988). I collected feces from the holding bag for diet analysis. To record echolocation calls from known individuals, I recorded echolocation calls using ANABAT II ultrasonic detectors (Titley Electronics, Ballina, N.S.W., Australia). This reference call library of known species was collected to assist in identification of calls from unknown individuals (see below).

Foraging Ecology

The ultrasonic echolocation sounds of most bats are inaudible to human hearing. Sequences of calls are often classified into two types. A 'pass' is defined as a sequence of two or more individual calls. Bats use these types of calls when commuting or foraging. Passes are separated from one another by at least one second, the amount of time required for the delay switch on the bat detector to be activated (Titley Electronics). A 'feeding buzz' is characterized by a high call repetition rate, and it occurs when a bat closing in on an insect (Griffin et al., 1960). Feeding buzzes, actually sound like a buzz and are easily discernible from passes.

ANABAT II detectors detect the inaudible, ultrasonic echolocation sounds of bats and output them as a fixed proportion of the original call, thus making them audible to the human ear. I coupled these detectors with ANABAT II delay switches and tape recorders, which allowed for remote all-night recordings. Detectors were placed one meter off the ground, facing upwards at an angle of 30° in a natural opening within the habitat type, at least 50 meters away from forest edges (ie. roads or other habitat types) or water sources.

Recorded bat echolocation calls were transferred from tapes to computer files via ANABAT call analysis software, and a cassette recorder coupled with a ZCAIM (zero crossings analysis interface module). ANABAT call analysis software visualizes these calls in a time-frequency display. I am presently analyzing these calls to differentiate between species or species groups.

Statistical Analyses

The remote detection study is a two-factor (Model I) design. To compare bat activity levels between ecosystem zones and forests of different ages, I used analysis of covariance (ANCOVA) with pass-rate (number of bat passes per hour) as the dependent variable, ecosystem zone and stand age as independent variables and ambient temperature as a covariate. Multiple analysis of variance (MANOVA) will be used to separate bats to species or species groups by the morphology of their echolocation calls.

RESULTS AND DISCUSSION

During the 2000 field season, 24 nights of netting (85 net-nights, where one net open for a night is equal to one net-night) yielded 74 bat captures, representing seven or eight species (Table 4). Netting locations are displayed on the map of the study area (Figure 1). Species diversity was consistent with that found by a previous inventory of the area (Firman and Barclay 1993). The three most commonly captured species were the California Myotis, Little Brown Myotis and Yuma Myotis. Female bats represented 79% of total captures (Table 4). Netting effort was much higher in the IDFww than in other zones. In the 2001 field season, netting effort will be spread more equally across all biogeoclimatic zones.

On 75 detector-nights (where one detector set out for a night is equal to one detector-night), 1565 foraging passes and 71 feeding buzzes were detected. Detector locations are displayed on the map of the study area (Figure 1). Nightly activity data were converted to rates (number of passes per hour) and were $\log_{10}$-transformed to meet assumptions of normality. Ambient temperature did not influence activity level, so I removed it from the analysis. Because a single measure of temperature is unlikely to account for the range of temperatures in different habitats, in 2001, I will use Thermocron temperature sensors (i-buttons) to measure temperature at each detector site.

Bat activity (mean number of passes per hour, log-transformed) was highest in the Ac zone and lowest in the CWHms1 zone (Figure 2). I attribute the low activity in the CWHms1 zone to its higher vegetation density compared to other zones, although density has not yet been analyzed. There was a clear trend of increasing bat activity with increased forest age (Figure 3). There was a significant effect of stand age on bat activity between young and old forests (ANOVA, $F_{[2,48]} = 3.81$, $P = 0.029$). In the Ac, IDFww and CWHms1 ecosystem zones, bat activity increased with increased forest age (Figure 4). This trend was not observed in the ESSFmw, possibly because young stands were very open, unlike the young stands of other zones.

CONCLUSION

The northern Skagit watershed supports a high diversity of bat species. Black cottonwood forests appear to be important to foraging bats in the area. This higher activity may be associated with higher insect densities in these riparian-associated forests, or perhaps black cottonwood stands provide excellent roosting habitat for bats. Further work should help to clarify these relationships as well as the reasons for lower activity in the CWHms1 zone. The results of this study suggest that bats are using older forests more often than young or medium-aged forests, possibly due to a higher number of available roost sites in older stands. Comparison of bat foraging activity in forests and in riparian zones will further determine the role of these habitat types. In addition, determination of roost selection by bats in the area will provide important information that can be applied to land and forest management plans to ensure conservation of bats in the Skagit watershed. An interesting result to note is that pregnant little brown bats, *Myotis lucifugus*, were captured at an elevation of 1200 m. This is unusual based on the results of previous studies (Barclay 1991). A second field season will be conducted to strengthen these results and provide new information about bat habitat use in the northern Skagit watershed. The preliminary results of this work have begun to increase our understanding of bat habitat use in terms of specific forest attributes; namely, biogeoclimatic zone, species composition and forest age.

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Table 1. Bat species potentially found within the Skagit Watershed and presence/absence in 2000. Provincial status information is from British Columbia 1996 Red/Blue/Yellow List for Terrestrial Vertebrates. Symbols in the "Captured/Heard in 2000" column represent the following: +=confirmed, ?=unconfirmed

Common Name	Scientific Name	Provincial Status Listing	Captured/Heard in 2000
Western Red Bat	*Lasiurus blossevillii*	red	
Keen's Long-eared Myotis	*Myotis keenii*	red	?
Townsend's Big-eared Bat	*Corynorhinus townsendii*	blue	
Western small-footed Myotis	*Myotis ciliolabrum*	blue	
Big Brown Bat	*Eptesicus fuscus*	yellow	+
Hoary Bat	*Lasiurus cinereus*	yellow	?
Silver-haired Bat	*Lasionycteris noctivagans*	yellow	+
California Myotis	*Myotis californicus*	yellow	+
Western Long-eared Myotis	*Myotis evotis*	yellow	+
Little Brown Myotis	*Myotis lucifugus*	yellow	+
Long-legged Myotis	*Myotis volans*	yellow	+
Yuma Myotis	*Myotis yumanensis*	yellow	+

Table 2. Climatic characteristics of the ecosystem zones involved in the study of bat habitat use in the northern Skagit watershed. Information taken from Green and Klinka (1994).

	Ac[a]	IDFww[b]	CWHms1	ESSFmw
Elevational range (m)	500-1350	500-1200	650 - 1350	1300 - 1650
Annual precipitation (mm)	1198-1415	1198	1415	1524
May-September precipitation (mm)	176-265	176	265	288
Mean annual temperature (°C)	5.7-9.2	9.2	5.7	1.8
Mean temp. of warmest month (°C)	15.3-20.4	20.4	15.3	12.1
Frost free period (days)	116-204	204	116	32
Winters (temp, moisture)	cool, moist	cool, moist	cool, moist	cold, long
Summers (temp, moisture)	warm/cool, dry	warm, dry	cool, dry	cool, short

[a] Range from values for IDFww and CWHms1

[b] Based on location outside Skagit

Table 3. Age classes, with age ranges in brackets, of the three age group classifications used in this study for the Ac, IDFww, CWHms1 and ESSFmw ecosystem zones in the northern Skagit watershed (Y=young, M=medium and O=old).

Age Class	Ac	IDFww	CWHms1	ESSFmw
1 (1-20)	Y	Y	Y	Y
2 (21-40)	Y	Y	Y	Y
3 (41-60)	M	Y	Y	Y
4 (61-80)	M	M	M	M
5 (81-100)	O	M	M	M
6 (101-120)	O	M	M	M
7 (121-140)	.	O	O	O
8 (141-250)	.	O	O	O
9 (251+)	.	O	O	O

Table 4. Summary of bat captures by Biogeoclimatic zone in the Skagit watershed. (EPFU = *Eptesicus fuscus*, LANO = *Lasionycteris noctivagans*, MYCA = *Myotis californicus*, MYEV = *M. evotis*, MYKE = *M. keenii*, MYLU = *M. lucifugus*, MYYU = *M. yumanensis* and MYVO = *M. volans*.)

Biogeoclimatic zone	Species	Female	Male
IDFww			
(60 net nights)	EPFU	0	1
	LANO	0	1
	MYCA	21	6
	MYEV	2	0
	MYKE	0	1
	MYEV/KE[1]	1	0
	MYLU	4	0
	MYYU	2	3
	MYLU/YU[1]	7	1
	MYVO	3	1
CWHms1			
(7 net nights)	MYYU	1	0
ESSFmw			
(16 net nights)	MYEV	1	1
	MYLU/YU[1]	15	0
Total		57	15

1. Unidentifiable as either species

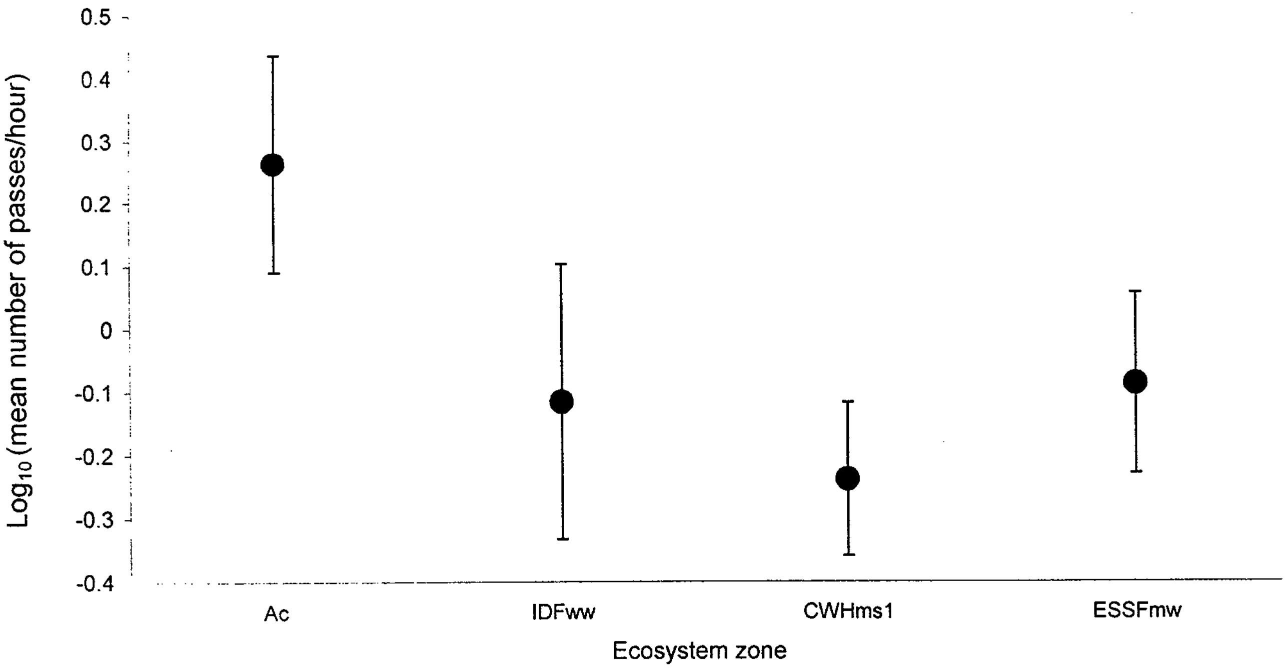

Figure 2. Mean activity of bats (measured by mean number of passes per hour) by ecosystem zone in the northern Skagit watershed study area.

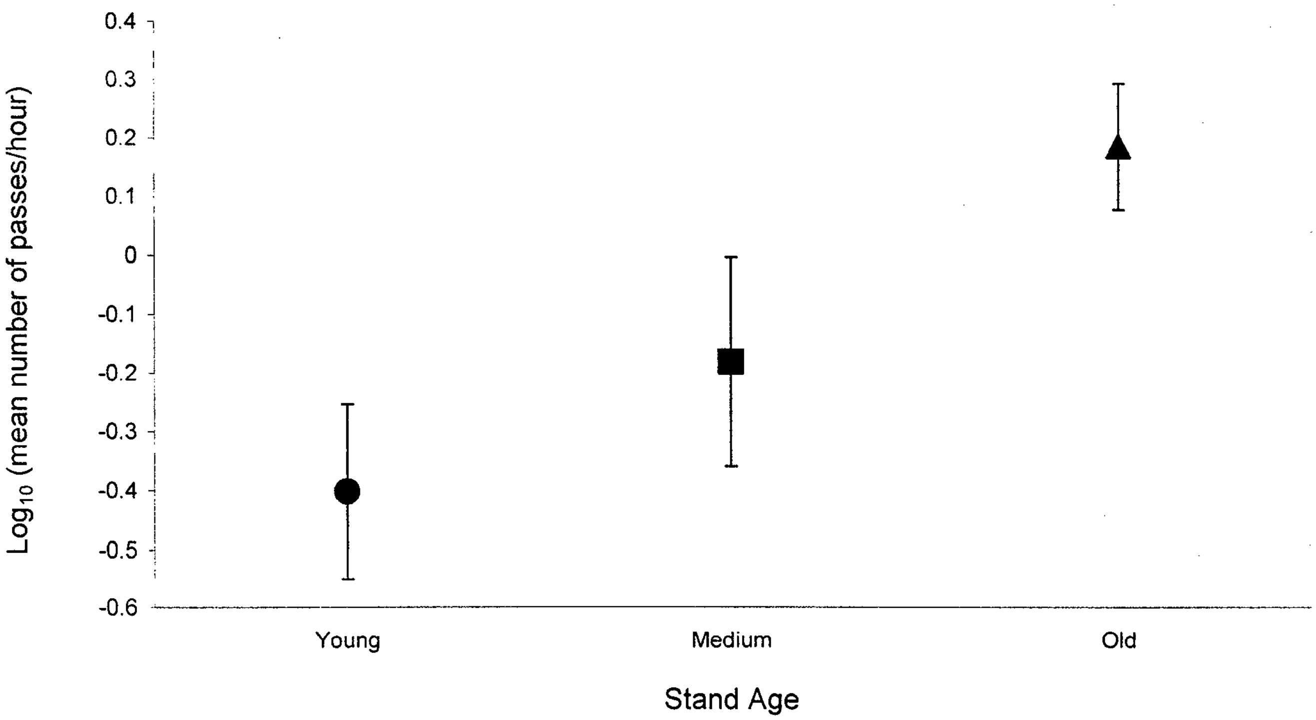

Figure 3. Mean bat activity (measured as mean number of passes per hour) by forest age (with all ecosystem zones combined) in the northern Skagit watershed study area.

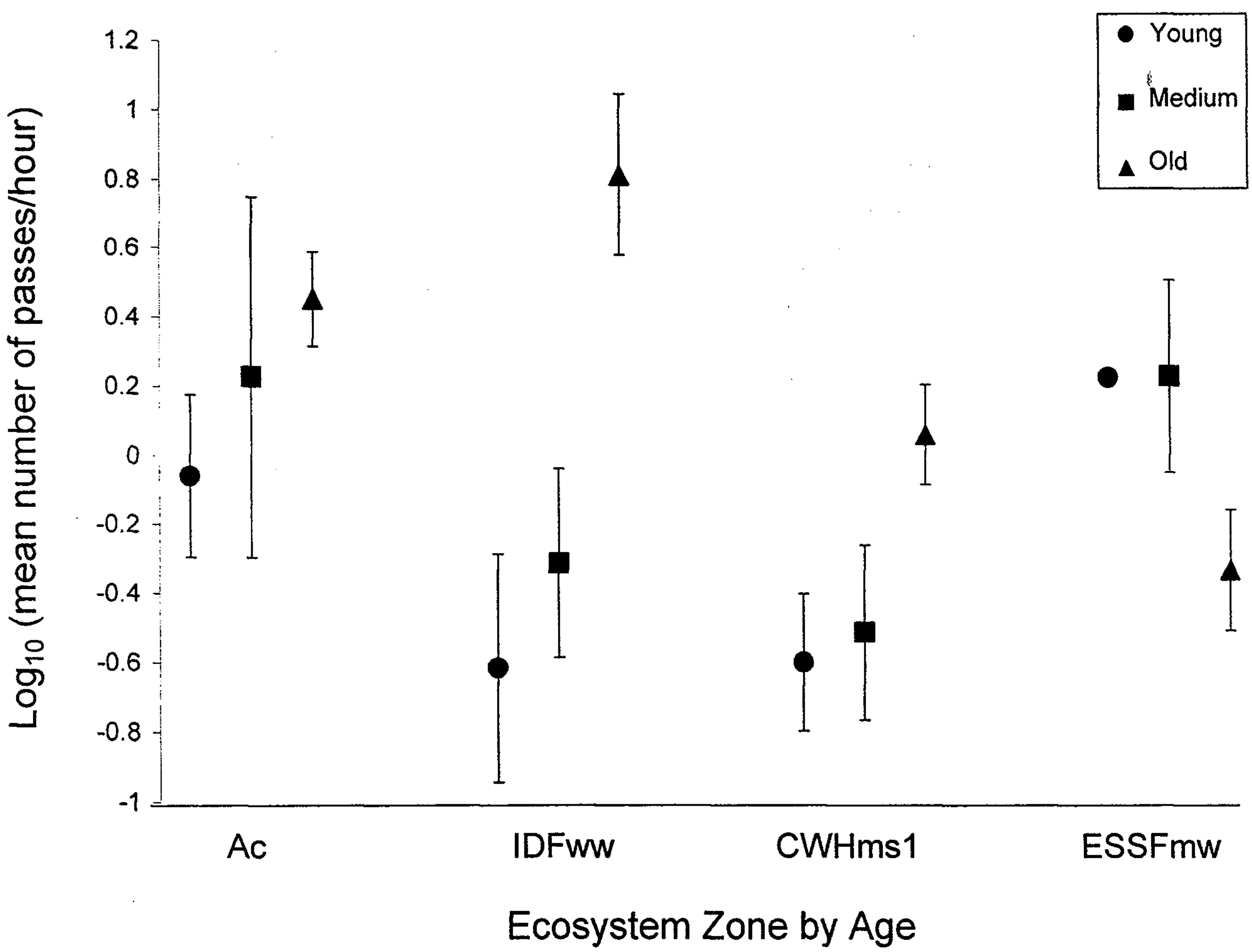

Figure 4. Mean bat activity (measured as mean number of passes per hour) by ecosystem zone and forest age in the northern Skagit watershed study area.