BAT INVENTORY IN OLYMPIC NATIONAL PARK

Prepared for

Olympic National Park

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Introduction

The National Parks Omnibus Management Act of 1998 mandated an inventory program to establish a baseline of information for park management. The inventory plan for the North Coast and Cascades Network, of which Olympic National Park (ONP) is a member, strives to verify at least 90% of vertebrate species that might inhabit network lands. Bats have not received the attention of other groups and require additional work to reach this goal. Some surveys have been done recently in the Park and are a valuable starting point for construction of the verified species list (Erickson et al. 1998, 1999; Fleckenstein 1998). This report augments these efforts.

Within the Pacific Northwest 17 bat species are thought to be present: California myotis (*Myotis californicus*), western small-footed bats (*Myotis ciliolabrum*), long-eared myotis (*Myotis evotis*), Keen's myotis (*Myotis keenii*), little brown bats (*Myotis lucifugus*), fringed myotis (*Myotis thysanodes*), long-legged myotis (*Myotis volans*), Yuma myotis (*Myotis yumanensis*), western pipistrelles (*Pipistrellus hesperus*), pallid bats (*Antrozous pallidus*), big brown bats (*Eptesicus fuscus*), spotted bats (*Euderma maculatum*), silver-haired bats (*Lasionycteris noctivagans*), hoary bats *(Lasiurus cinereus),* western red bats (*Lasiurus blossevillii*), Townsend's big-eared bats (*Plecotus townsendii*) and Brazilian free-tailed bats (*Tadarida brasiliensis*). Of these, pallid bats, western red bats, spotted bats, western small-footed bats, western pipistrelle, and Brazilian free-tailed bats are not likely to be in the area of the Olympic National Park (Erickson et al., 1999), leaving 11 species potentially occurring within Park boundaries.

The Olympic National Park has been surveyed previously by Janet Erickson, Kurt Jenkins, and Justin Yeager in 1998 and 1999. The abandoned mines within the Olympic National Park were surveyed in 1998 by John Fleckenstein. Other trapping has taken place from 1998-2000 at various locations within the park.

When comparing continuous forest blocks, the bats of the Pacific Northwest have higher activity levels in old-growth forests than young and mature forests (Thomas and West, 1991). Generally, they prefer forests for roosting and clearings and bodies of water for foraging. Bats travel from forests to water by habitual flyways not only to get water to drink but also to forage on insects that are attracted to the water. In fact, 10 times greater feeding rates occur over water than occur near the roosting areas of the forest (Christy and West, 1993).

Within the forest, local bat species prefer to roost in trees. They roost in cracks, peeling bark, foliage, hollows abandoned by woodpeckers and cavities of snags (Erickson, 1998 and Kalcounis et al. 1999).

The climate of the Pacific Northwest ranges from cool and wet in certain areas to warm and dry in others. Bats in this region prefer areas that have high abundance of nocturnal, flying insects. Bats are small and have high surface area to volume ratios (Lausen, 2002). They must either forage continuously to maintain homeothermy, or adjust to an unfavorable energy balance by using energy conservation strategies. Such strategies include daily torpor, seasonal migration, and winter hibernation. Collectively, these strategies allow bats to survive in parts of the world that would be unlivable for small mammals that continuously maintained a high body temperature.

The diverse environmental gradients on the Olympic peninsula present many interesting research questions for bats. The east side of the peninsula is far drier than the unprotected west side and may provide habitats more amendable to bats due to a presumed greater activity of nocturnal flying insects. Differences in humidity and temperature with changes in elevation may also influence bat presence and activity as a function of insect activity. Different forest types, such as Sitka spruce and Western hemlock/Douglas-fir may also show differences in bat species composition (Erickson et al., 1999).

While the primary goal for the bat survey was to verify bat species presence in the Park, we documented occurrence in a systematic way that provided additional insight into the patterns of bat species occurrence on the Olympic Peninsula. We expected that the strong environmental gradients of the peninsula would affect not only bat species presence, but also their population structure and reproductive biology. As we collected information on bat species presence we investigated the influence of elevation, precipitation, and selected vegetation types on bat distribution.

As indicated in the Cooperative Agreement for the study, we had four objectives for the survey:

1. Verify the bat species list for ONP
2. Gain additional insight in bat distribution relative to elevational gradients in ONP
3. Gain additional insight in bat distribution relative to precipitation gradients in ONP
4. Gain additional insight into bat distribution relative to vegetation types in ONP

The first objective was the primary goal of the survey. Objectives 2-4 were addressed with data collected for the first objective. The project has produced a project report summarizing the work (this report), provided a sampling database, a collection of hair samples for subsequent DNA analysis for species confirmation, and three theses addressing objectives 2-4.

The Theses

Undergraduate theses are appended. Influence of elevation on the bats (objective 2) was addressed by Elizabeth Bickford with her thesis, "Segregation of male and female Vespertilionid bats by elevation on the Olympic Peninsula" (Appendix 2). Michelle Noe investigated the precipitation gradient (objective 3) with her thesis, "Precipitation Gradient and its Effect on Species Composition and Sex Ratios" (Appendix 3). Patrick Adam looked at bat species composition with respect to two major forest types on the peninsula (objective 4) with his thesis, "Relative species composition of bats in Sitka spruce and Western hemlock forests on the Olympic Peninsula".

Methods

Study Area

The Olympic National Park is situated in the middle of the Olympic Peninsula in Washington, covering almost 5000 km^2 (Whitney 1983, McNulty 1996). The park consists mostly of mountains, but also encompasses a long narrow strip of low land along the Pacific coast (McNulty 1996). Within these mountains, no peak is more than thirty miles from salt water (Whitney 1983). From sea level to the top of Mt. Olympus is a sharp elevation gradient, with an elevation gain of 2428 m (Whitney 1983). This region receives extremely variant amounts of rainfall with less than 51 cm a year in the rain shadow of the Olympic Mountains to more than 500 cm a year in the Hoh rainforest (Whitney 1983, McNulty 1996). As a result of this climate range, there is an observable change in the flora and fauna from the west to the east side (McNulty 1996).

Site Selection

Selection of both ultrasonic monitoring locations and direct capture sites within Olympic National Park (herein referred to as the Park) was guided by the primary objective of assessing species presence across the entire park. The three secondary objectives of the study were used to guide site selection along gradients represented by high and low elevation sites, wet and dry sites, and sites dominated by a Sitka spruce (*Picea sitchensis*) or Western hemlock (*Tsuga heterophyla*) forest series.

To characterize the elevation and precipitation gradient in the park, sites were chosen on the wet, west side of the park and in the rain shadow on the dryer, east side of the park. All sample locations are indicated in Figure 1.West side sites were established at Three Lakes at an elevation of 940 – 980 m (Figure 2) and in the Quinault River drainage between the confluence of the North Fork Quinalt and Lake Quinault at an elevation of 60 – 140 m (Figure 3). The eastern dry sites included locations on the Miller Peninsula at an elevation of 30 – 100 m representing the lower end of the elevational gradient (Figure 4), Deer Park at an elevation of approximately 1200 m, and locations along the Hurricane Hill Road at an elevation of 790 – 1375 m representing the higher end of the elevational gradient (Figure 5). Although direct capture and echolocation sites on Miller Peninsula were 9 km from the nearest segment of the Park, no suitable site was found within the Park that was below 300 m and received less than 500mm of rain annually.

To understand bat species composition in Sitka spruce forest, we established study sites along the Hoh River near the Hoh Ranger Station (Figure 6), along the Queets River near the Queets Ranger Station (Figure 7), and at Lake Ozette (Figure 8). Likewise, study sites were established near Goodman Creek (Figure 9), and Boulder Creek (Figure 7) on DNR land bounded to the north by the Bogachiel River and to the south by the Queets River to determine bat species composition in Western hemlock forests. While these last two sites are not contained within the Park proper, we selected them based on relatively easy access by forest road and the low elevation (less than 350 m) at which these Western hemlock/Western redcedar stands were found. Additionally, these stands were among the remaining few in this part of DNR land that had been spared any logging activity and retained the elements of old growth forest including large live trees (dbh > 32 inches), large snags, a multi-layered canopy and large coarse woody debris on the forest floor. While this forest composition and structure exists in the Park as well, the ideal stands are located on either side of the Hoh and Queets rivers, bounding the Sitka spruce stands in these river bottoms. Our choice not to establish study sites in these Western hemlock forests was based on their elevation (above 500 m) and the difficulty with access as

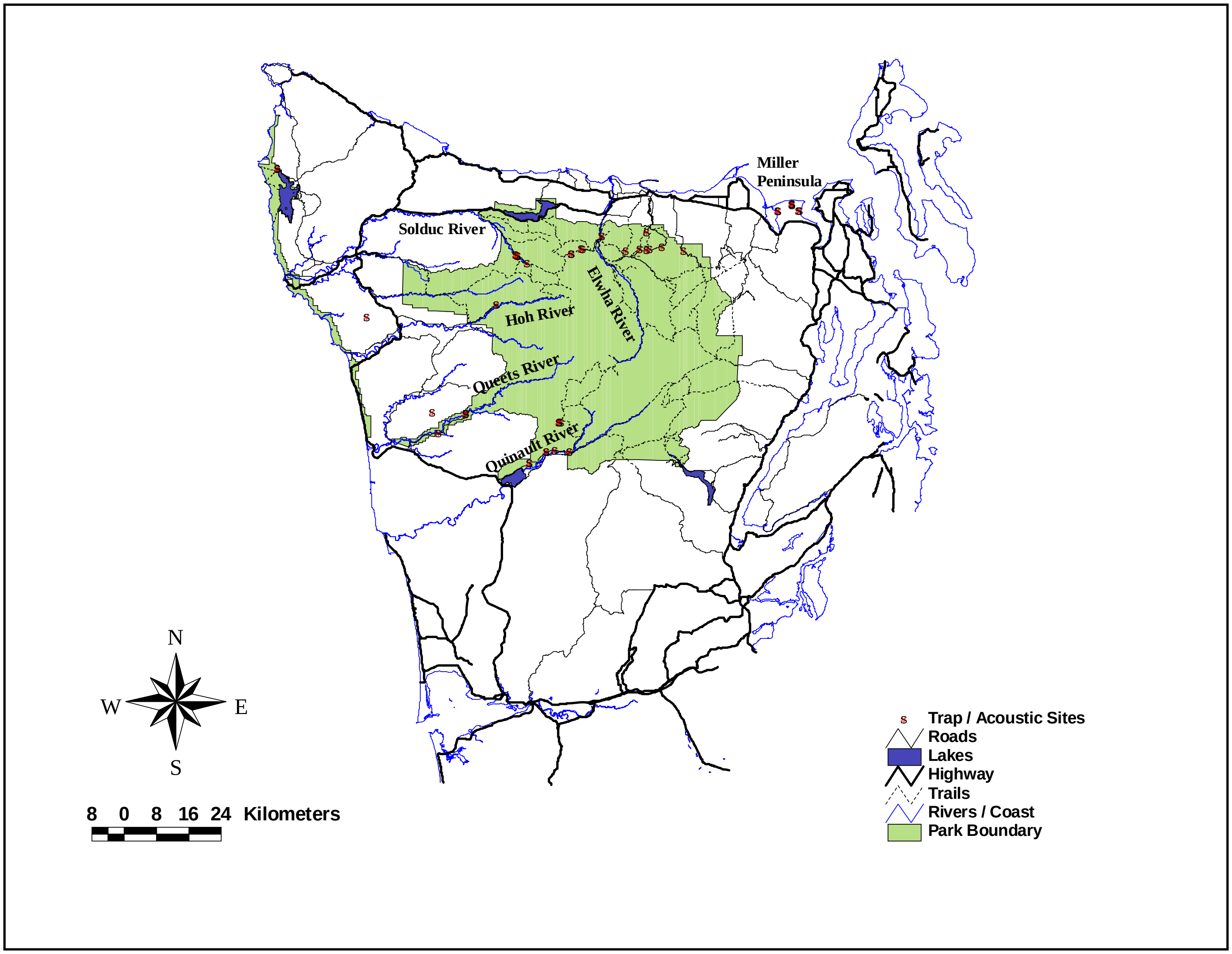

Figure 1. Location of live capture and acoustic sample sites. Olympic National Park, 2003.

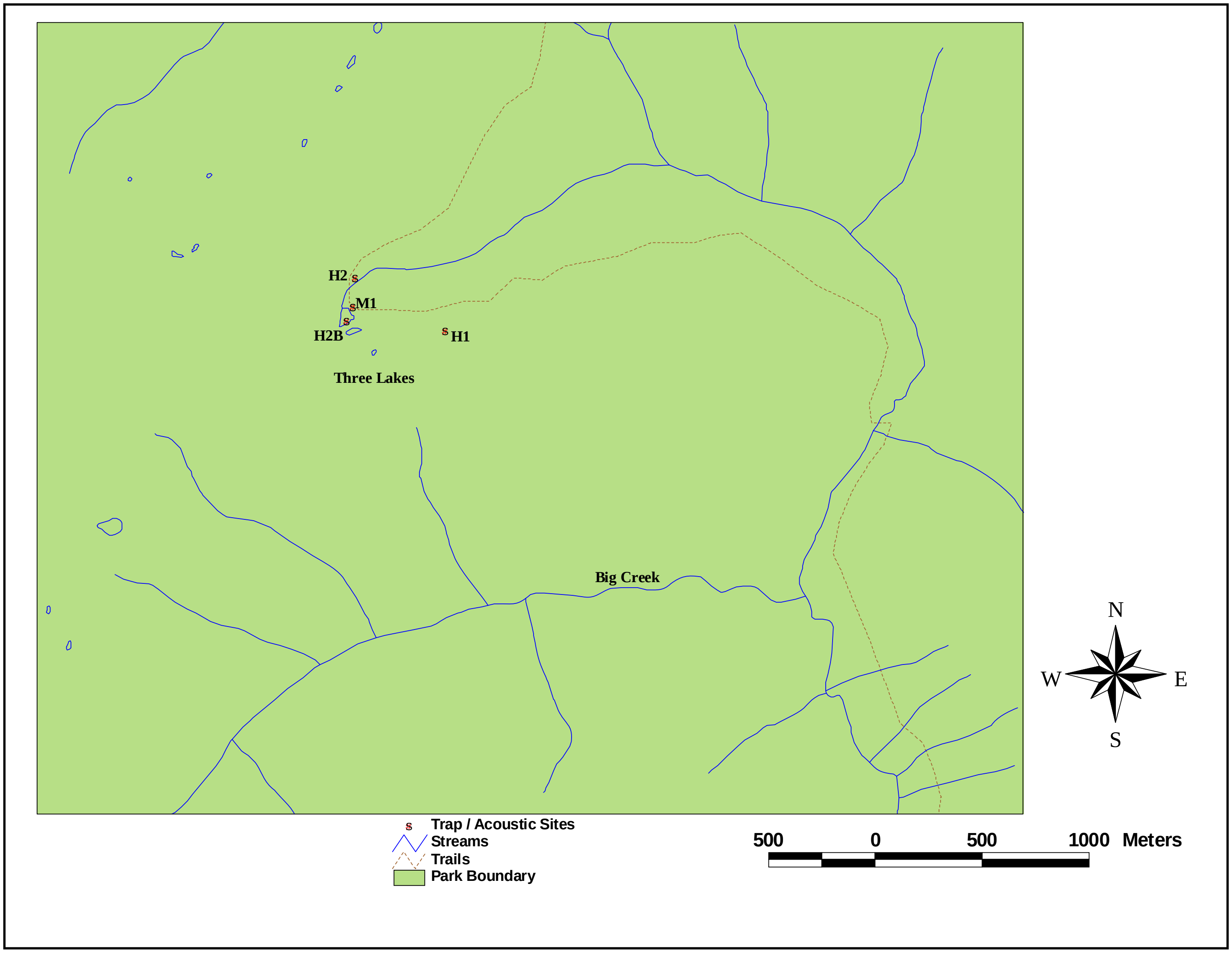

Figure 2. Harp trap and mist net sites at Three Lakes, N. Quinault drainage, 2003.

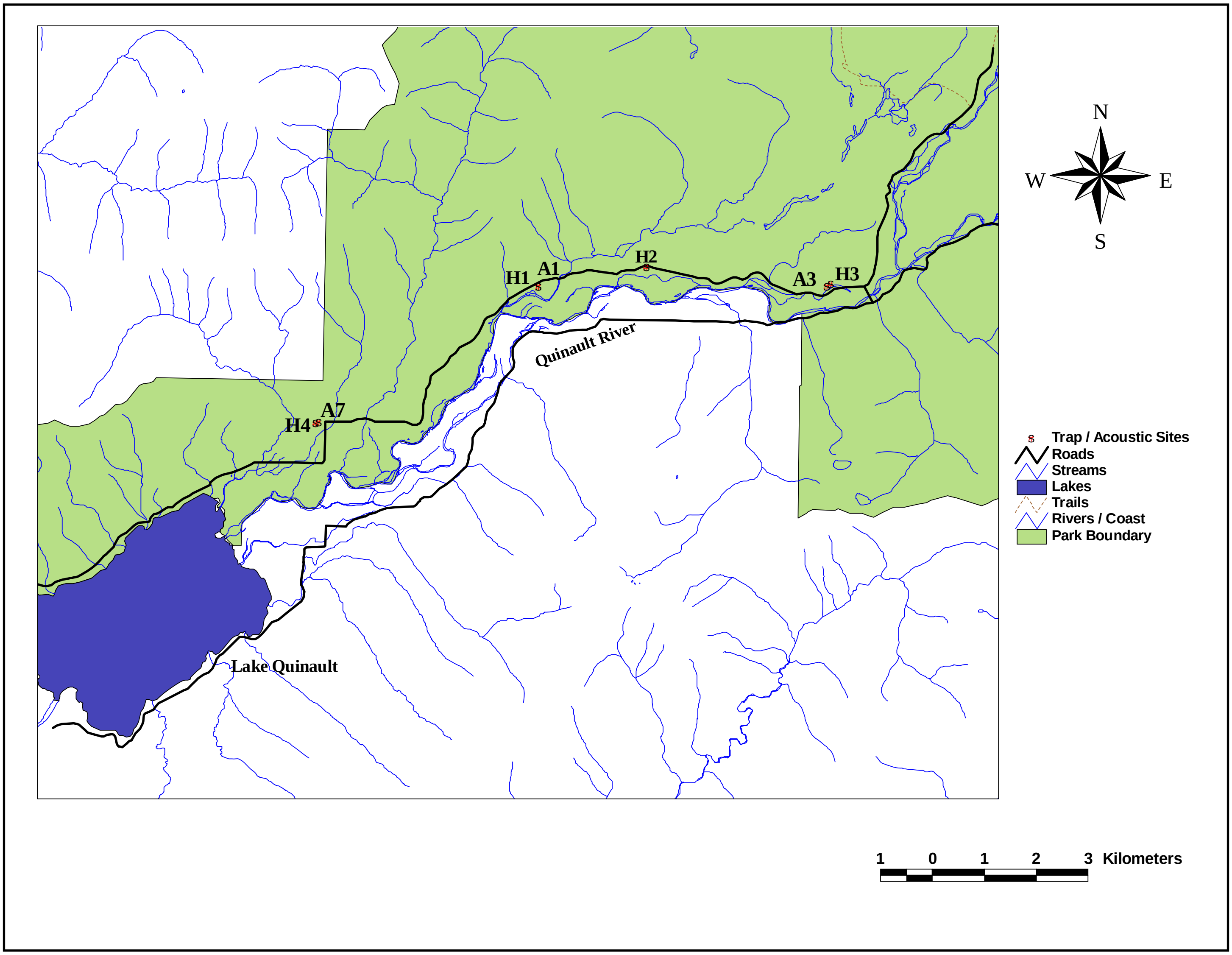

Figure 3. Harp trap and acoustic sample locations. Quinault River, 2003.

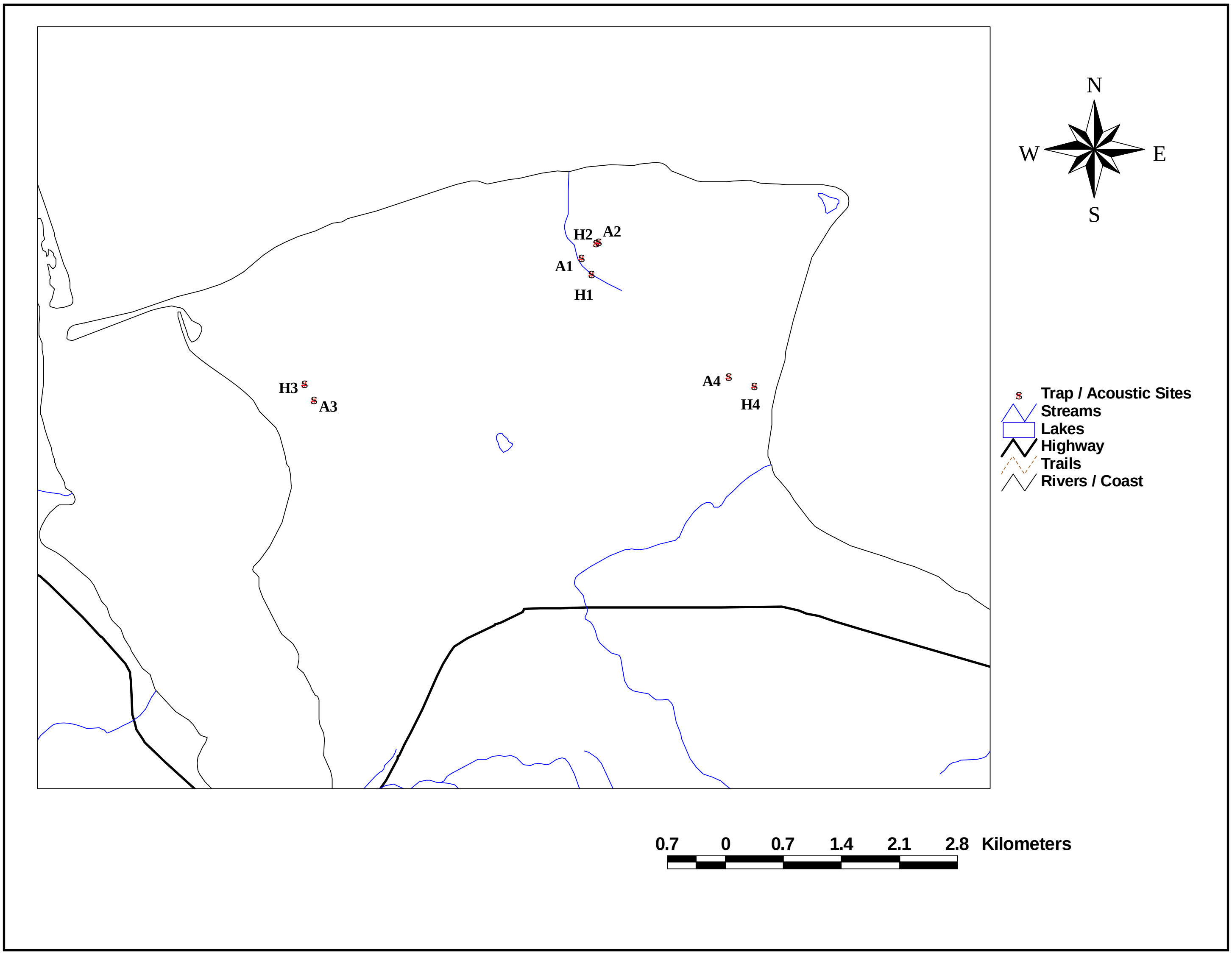

Figure 4. Harp trap and acoustic sample locations. Miller Peninsula, 2003.

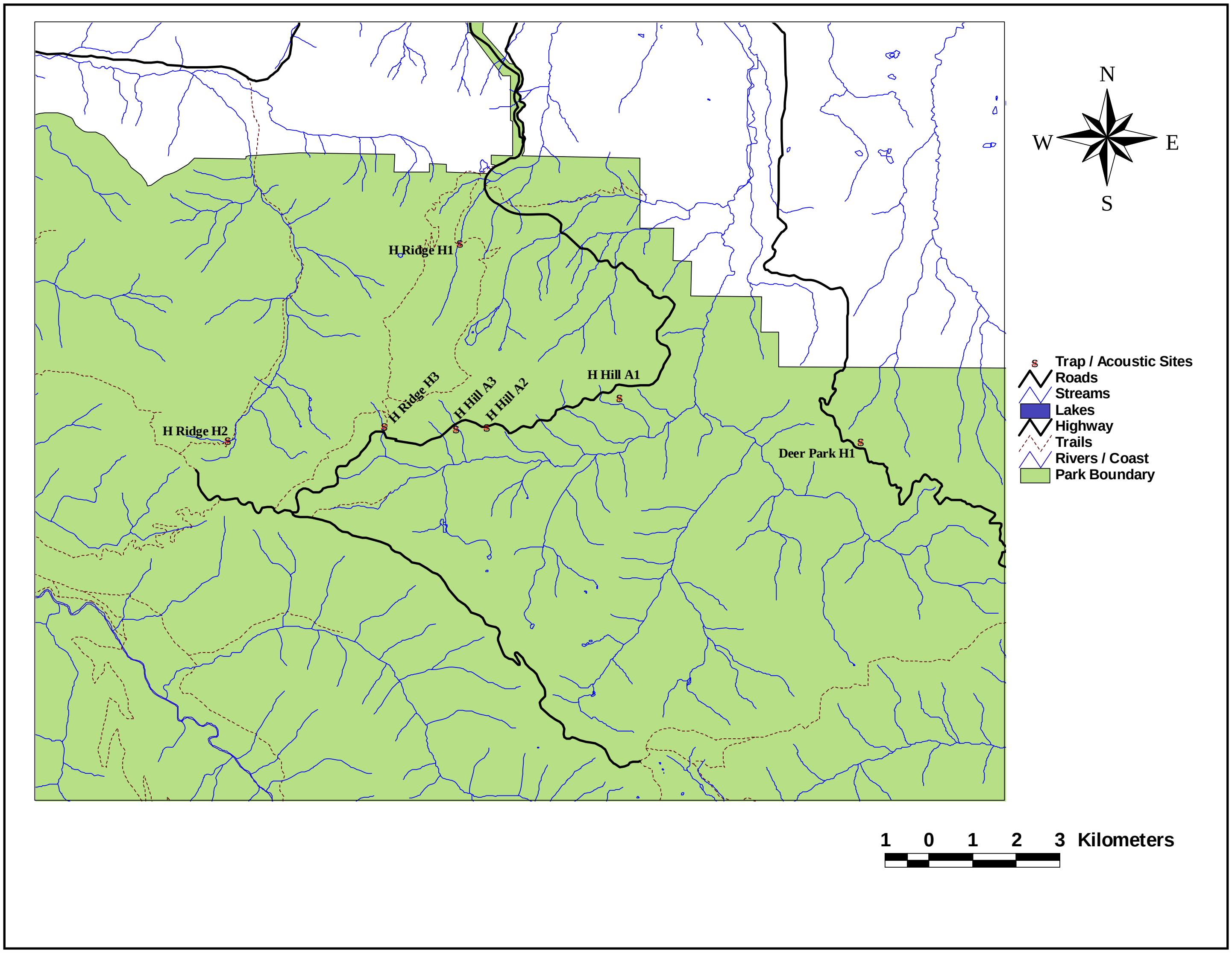

Figure 5. Harp trap and acoustic sample locations. Hurricane Hill and Deer Park, 2003.

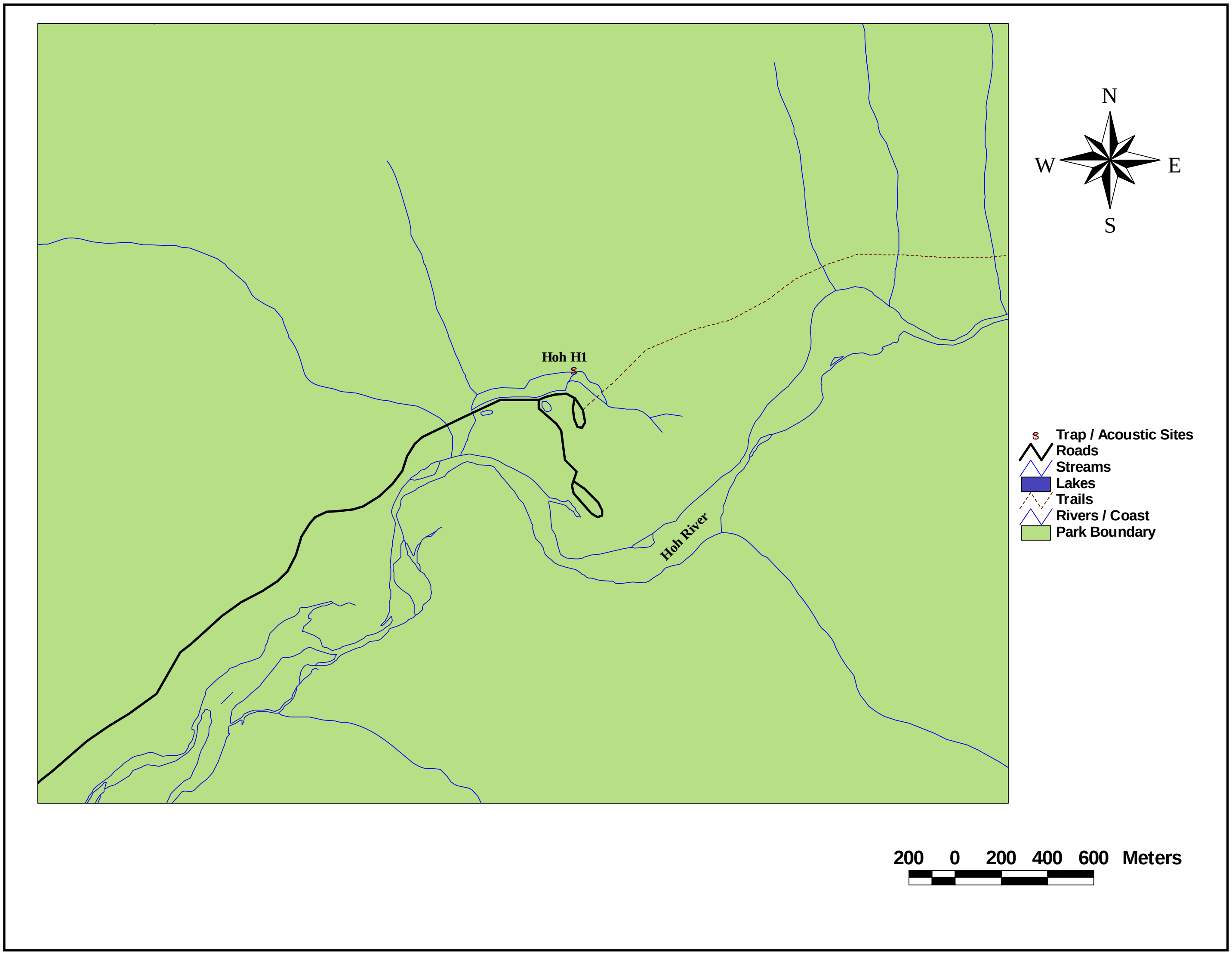

Figure 6. Harp trap and acoustic sample locations. Hoh River, 2003.

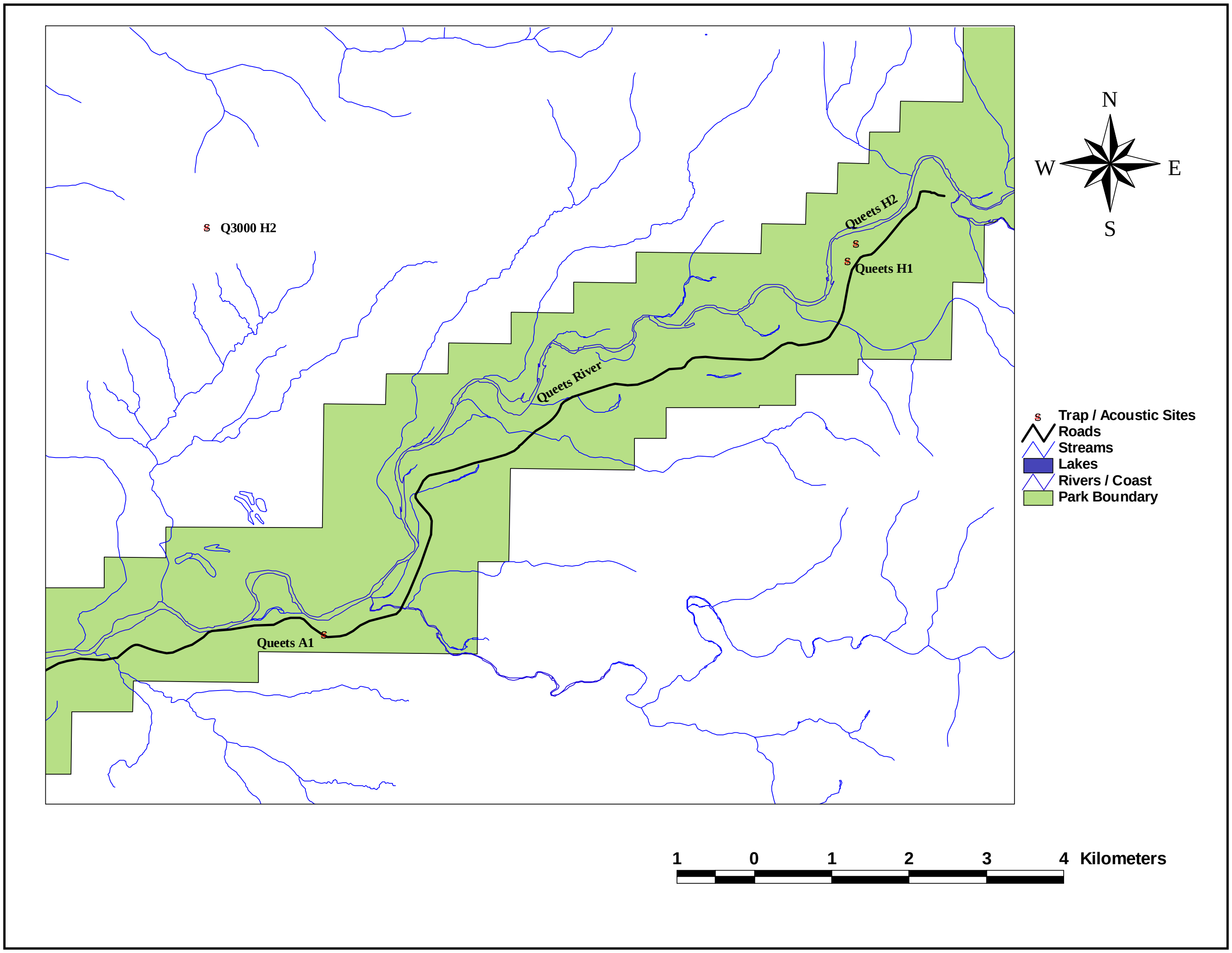

Figure 7. Harp trap and acoustic sample locations, Queets River. Boulder Creek site accessed by DNR road Q3000, 2003.

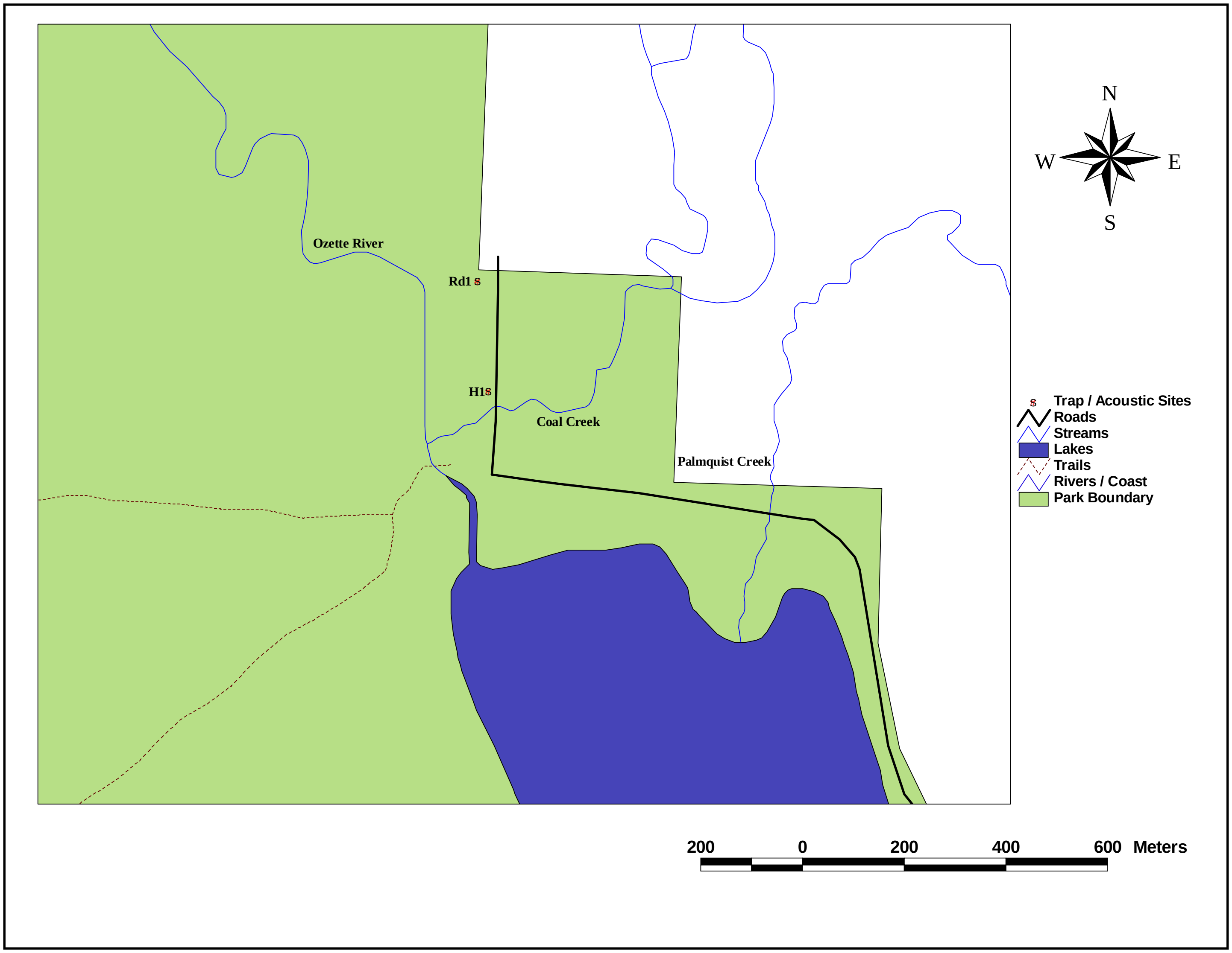

Figure 8. Harp trap locations. Lake Ozette, 2003.

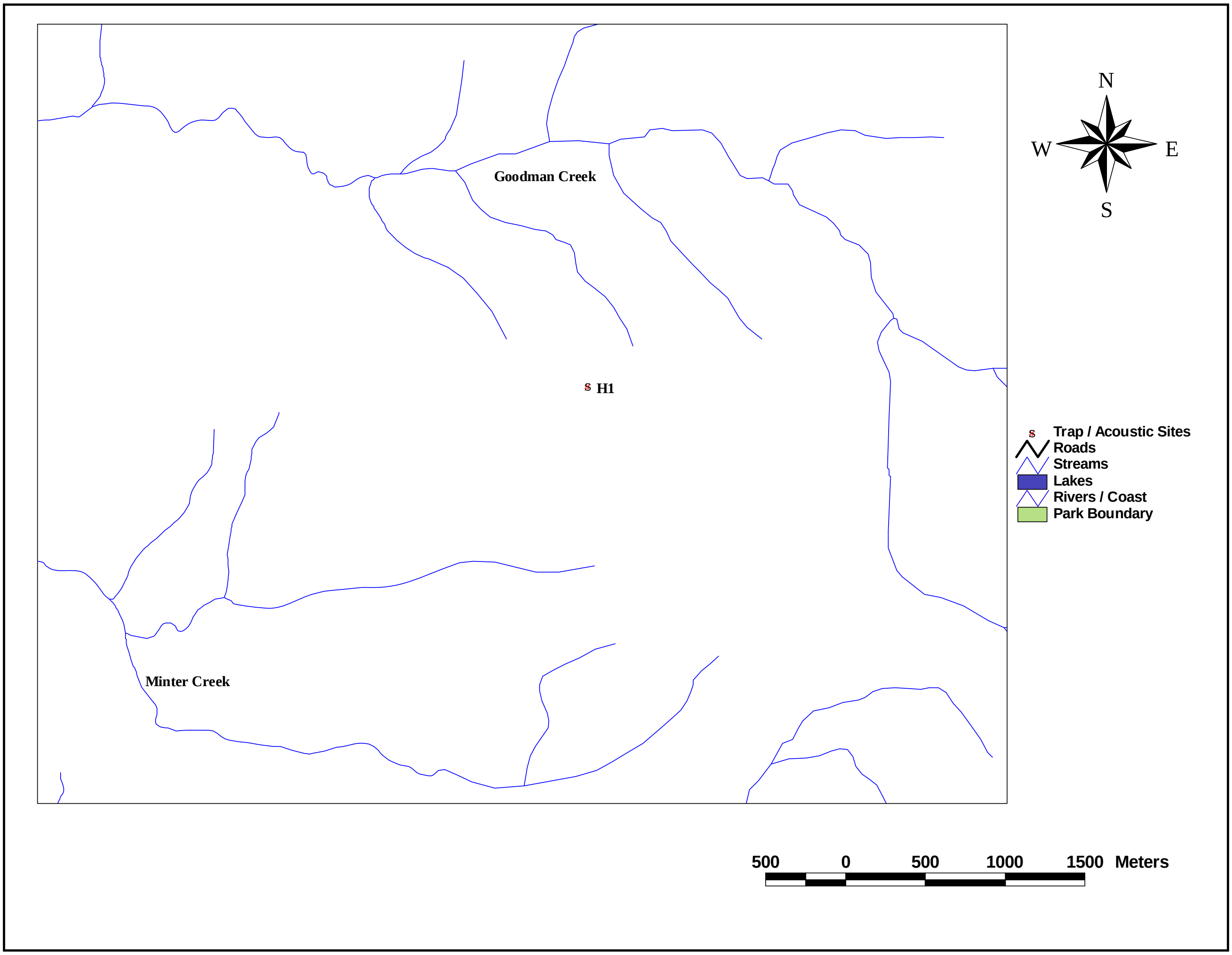

Figure 9. Harp trap location. Goodman Creek, 2003.

there are no roads or trails that enter this forest type in the Hoh and Queets river drainages. The higher elevation was a problem due to the possibility of confounding the effects of forest series on bat species composition with that of elevational influences.

Sites that were sampled in 1998 (Erickson *et al*., 1998) and 1999 (Jenkins *et al*., 1999) included locations in the Elwha and Quinault watersheds. We established sampling sites within the Elwha drainage (Figure 10) as well to contrast bat species diversity between these prior surveys and this current survey in 2003. We also added a general interest study site within the Soleduc River drainage (Figure 11) that spanned an intermediate elevational range of 480 – 610 m.

Field Methods

Direct capture methods were used to positively identify bat species while ultrasonic detection methods were used to identify general presence and relative activity between sites.

Morphological characteristics were measured and recorded including identification to species, sex, age, reproductive status, ear length, forearm length, foot length and weight. Regarding reproductive status, several factors were evaluated and recorded such as: pregnancy status, lactation status, and age. For all bats captured, elevation was noted. To check for pregnancy, the abdomen was palpated, with a large abdomen indicative of pregnancy (van Zyll de Jong 1985, Nagorsen and Brigham 1993, Racey 1973, Wilkinson and Barclay 1997, Henry et al. 2002, Racey 1988). Lactation status was checked by squeezing the nipples for milk release, with milk release indicating lactation (Racey 1973, Wilkinson and Barclay 1997). Females with swollen nipples and hair worn down around them were considered post lactating (van Zyll de Jong 1985, Nagorsen and Brigham 1993, Racey 1973, Wilkinson and Barclay 1997). Age, whether juvenile or adult, was determined by noting the pelage color, darker pelage indicating a juvenile (van Zyll de Jong 1985). Another method of determining age was by noting the ossification of the metacarpal-phalangeal joints (van Zyll de Jong 1985, Wilkinson and Barclay 1997). Males' sex was determined by the presence of a penis and females by the absence of one (van Zyll de Jong 1985). All individuals were released at the point of capture after having the opportunity to increase their normal metabolic rate from the state of torpor in which we examined them.

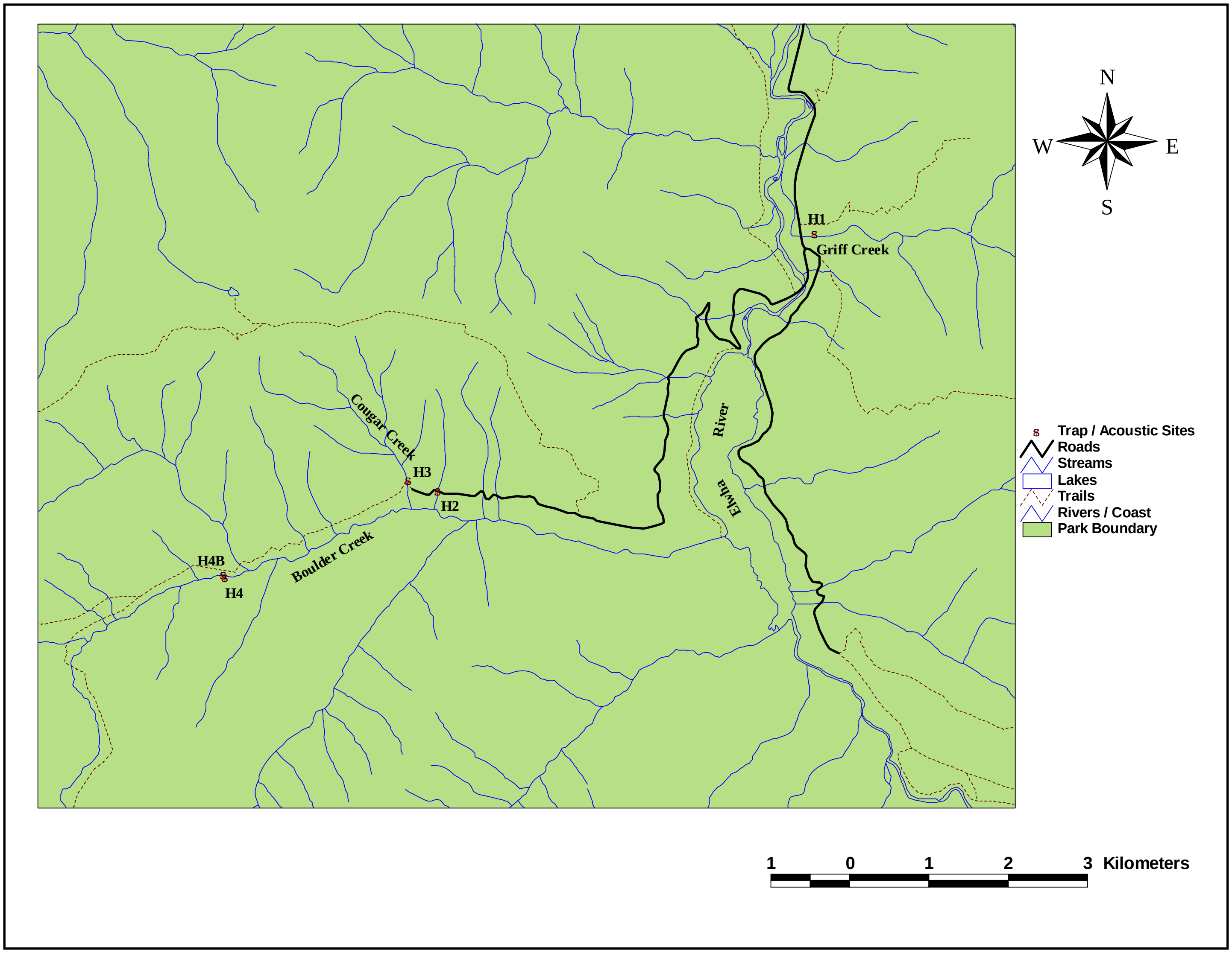

Figure 10. Harp trap locations. Elwha River, 2003.

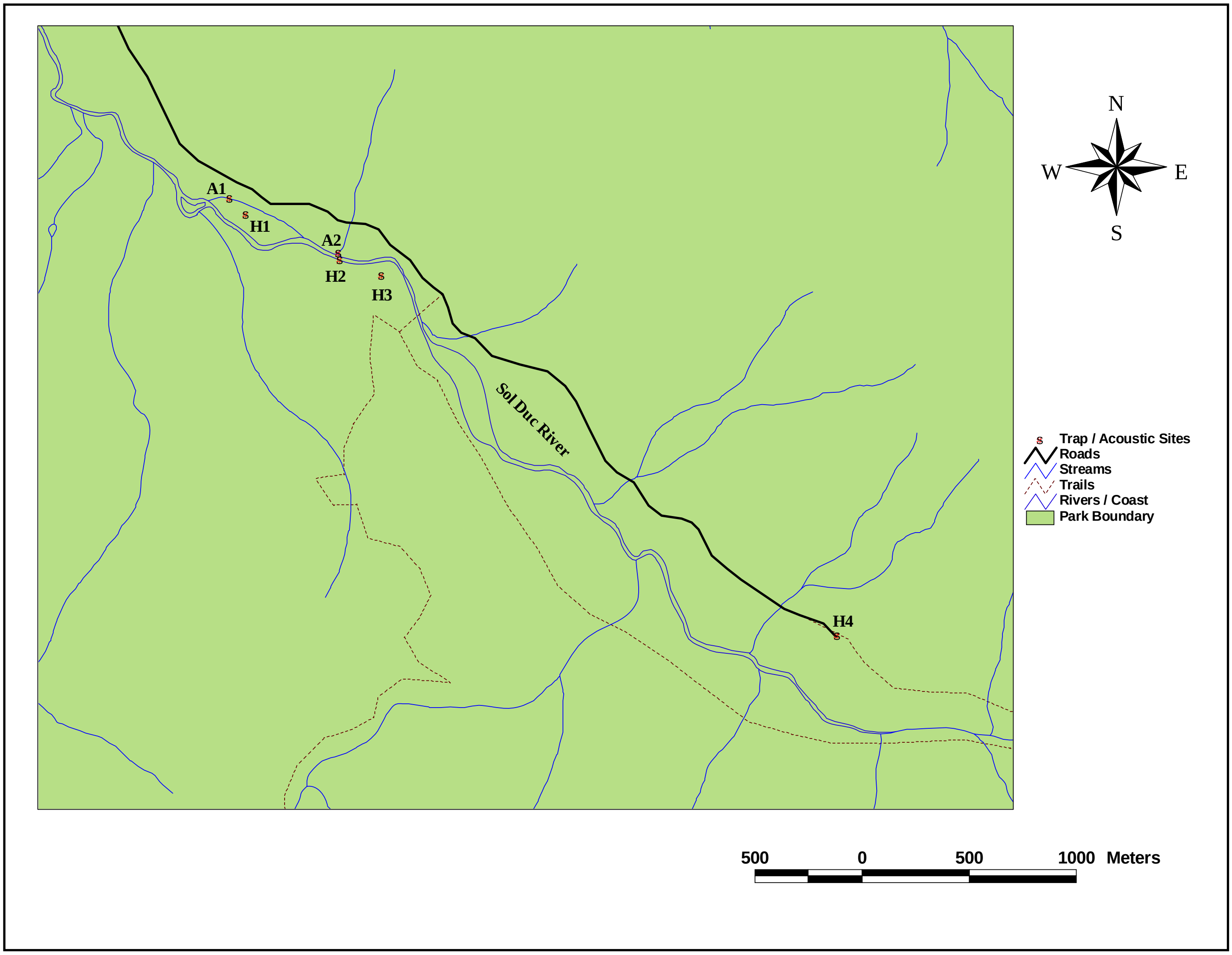

Figure 11. Harp trap and acoustic sample locations. Sol Duc River, 2003.

Harp Traps

Harp traps were placed in potential commuting corridors such as forest trails and narrow roads within the forest that lead to clearings and riparian areas. Harp traps are particularly useful with our limited personnel, as the majority of these traps were left unattended overnight, thereby increasing our ability to sample additional areas distant from each other in a given site that is otherwise not possible with mist nets that must be constantly monitored by two people and subsequently dismantled after dusk and dawn sampling events. Harp traps are relatively diminutive in size compared to the potential area of a flyway they are intended to sample from and as such are limited in their application. Care was taken to install these traps in corridors surrounded by dense foliage effectively leaving no alternative route for the bats to pass through. Additionally, due to the short stature of these traps (<3 m), high flying species such as the Hoary and Big brown bats are typically excluded from this sampling technique, effectively rendering these species as invisible. Although each harp trap weighs approximately 40 pounds, we decided to haul three of these traps up to the Three Lakes site above the North Fork Quinault, in addition to a mist net, based on our success in using these traps in other locations.

Hair Samples

Hair samples were taken from species not adequately sampled for DNA and from rare species such as *Myotis keenii.* A species was considered adequately sampled when 10 hair samples had been taken from representatives of the species. Samples were taken using tweezers to remove 5-10 hairs. Hairs were placed into plastic tubes with lab grade ethanol for preservation. Tubes were cross-referenced to bat identifiers in the live capture database. The hair samples will be analyzed by a lab in the future.

Mist Nets

Mist nets span a much larger area and are better suited for more open environments such as wide road cuts through forest interiors, clearings, over streams and near ponds. These nets are also prone to excluding the higher flying species unless placed to span a pond, in which case the bats may be intercepted when skimming the surface for a drink. One additional limitation of mist nets is the ability of bats to maneuver over the net when placed in foraging areas due to the slower flight and increased sensitivity bats have to objects when echolocating for insects. The placement height for effective capture depends on the landscape structure in which it is being installed. Mist nets were used in the meadow surrounding one of the ponds at the Three Lakes site. Our intent was to intercept the bats as they foraged for insects or skimmed the pond for a drink, but we only witnessed the bats actively avoiding the net by flying over or around it.

Acoustic Sampling

Acoustic sampling was done using ANABAT II detector systems. The systems were made up of the ANABAT II detector, a delay switch, a lead-acid battery, a cassette recorder and the necessary connecting wires. The detector systems were set up in a plastic storage container with a hole for the detector microphone pick-up and a piece of stiff plastic as a rain shield.

Site selection was done by siting the detectors greater than 100 m from the Tuttle traps. Sites were chosen in areas where there was open space surrounded by forest. Some examples of sites were the sides of trails and forest openings. The detectors were set in areas where they would not block access to trails and would not be disturbed. See Appendix 3 for a map of all detector sites.

The plastic box containing the detector system was elevated to an approximate 30 degree angle using sticks and other forest floor detritus at each site to receive as many calls as possible in the detection cone. The systems were checked for battery every day and the cassette tapes were flipped or replaced so that each night was recorded on its own side of a cassette tape. The delay switch was set for night detection and the sensitivity on the ANABAT II detector was set between 6 and 7. Due to the limitation of using cassette tapes as data storage, only 90 minutes of calls could be recorded each night. This limitation did not interfere with data collection on most nights.

Sampling with ANABAT II detectors was done as many nights as possible while live capture by Tuttle trap was taking place in an area. Detector malfunction limited the availability of working detectors on some nights.

Acoustic Analytic Methods

Cassette tapes were played and decoded using ZCAIM systems with sensitivity set between 6 and 7. The calls were converted to visual data files for analysis using ANABAT 6 software. The files were expanded to time = 1.6 seconds with all other settings remaining at default. Time stamp, recorder counter number and species detected were recorded. Species was determined by comparing the data on screen to known call structures. Due to variability in call structure between individuals it is difficult to distinguish between Myotis species when analyzing calls using ANABAT detection systems. Therefore, if a call was determined to have a structure similar to a known *Myotis* species call it was recorded as *Myotis sp*. due to high similarity between *Myotis* call structures.

Results

Direct Capture

Altogether 232 bats representing eight species were captured between June 18 2003 and August 3, 2003 (Appendix 1). All captures were made with the harp trap. Mist netting was unsuccessful. Of the total number captured, 44.2% were male, 55.8% were female, 96.1% were adult, and the remaining 3.9% were juvenile. These figures are based on a total of 231 bats, as one *M. lucifigus* escaped before sex or age could be determined. The highest proportion of females to males for a given species occurred at the Kestner Homestead near the Quinault Ranger Station, where 96% of the *P. townsendii* captured were female, 92% of which were in a reproductive state (pregnant or lactating). Out of the 232 bats captured, we were unable to positively identify to species 18 of these. The number of individuals captured normalized to sample nights in a given region is shown in Table 1 below. The low wet and dry sites yielded a combined average capture rate of 4.6 bats per sample night, while capture rates at the high wet and dry sites averaged only 0.22 captures per sample night. Capture rates at the wet high and low sites were 2.8 per sample night, while those of the dry high and low sites were 2.0 per sample night.

Hair Samples

Hair samples were successfully taken from seven species. Samples were taken from four individuals thought to be *Myotis keenii*, a species known to be rare in Olympic National Park. The lab analysis is pending and will not be complete before the final draft of this report. Complete results are shown in Table 2.

Table 1. Number of species captured in each region according to elevation and precipitation in Olympic National Park, June 18, 2003 through August 3, 2003. Sites within the Sol Duc and Elwha drainages were sampled to compare species composition with previous surveys in 1998 and 1999. Sitka spruce and Western hemlock forests were sampled to contrast species composition between different forest zones.

Region	Site Names	Number Captured	Sample Nights	Avg. Captures/ sample night	Species
Low Dry	Miller H1 Miller H2 Miller H3 Miller H4	63	16	3.94	MYCA MYVO MYLU MYTH LANO EPFU MYEV/MYKE
Low Wet	Quinault H1 Quinault H2 Quinault H3 Quinault H4	84	16	5.25	MYYU MYCA PLTO MYLU MYEV/MYKE
High Dry	Hurr. Ridge H1 Hurr. Ridge H2 Hurr. Ridge H3 Deer Park H1	1	16	0.06	MYCA
High Wet	Three Lakes M1 Three Lakes H1 Three Lakes H2 Three Lakes H2B	3	8	0.38	MYLU MYEV MYCA
Sol Duc Drainage	Sol Duc H1 Sol Duc H2 Sol Duc H3 Sol Duc H4	10	12	0.83	MYCA MYEV MYLU
Elwha Drainage	Elwha H1 Elwha H2 Elwha H3 Elwha H4 Elwha H4B	12	7	1.71	MYCA MYYU
P. sitchensis zone	Queets H2 Hoh H1 Ozette H1 Ozette Rd1	59	14	4.21	MYCA MYLU MYLU/MYYU MYTH
T. heterophyla zone	Goodman Cr. H1 Q3000 H2	0	8	0	-

Table 2. Number of individuals sampled by species**.** The table shows the number of samples taken of each species captured and tested during this study. Species listed is the suspected species determined by external characteristics and may be reclassified when lab analysis of the DNA is completed.

Species	***# Hair Sample***	***Total Captured***	***% Sampled***
PLTO	10	25	40.0%
MYEV/KE	4	6	66.7%
MYLU	9	63	14.3%
MYCA	18	117	15.3%
MYYU	2	10	20.0%
LANO	1	1	100.0%
EPFU	1	1	100.0%
MYEV	0	2	0.0%
MYTH	0	2	0.0%
MYLU/YU	0	4	0.0%
MYVO	0	2	0.00%
All Species	45	232	19.4%

Table 3. Percentage of bats according to species. This table breaks down the calls at each site accoustically sampled during the summer of 2003. Calls are distinguished as Myotis (positively identified as a Myotis species), Non-Myotis (positively identified as a species other than a Myotis species), or Unknown (any call not able to be identified as a particular bat species, but clearly identifiable as a bat call). Percentages are determined for each category at each site and then grand total percentages are listed under All Sites.

Site	***% Myotis***	***% Non-Myotis***	***% Unknown***	***Total Calls***
Solduc A2	63.5% (169)	1.9% (5)	34.6% (92)	266
Queets A1	0.0% (0)	31.3% (5)	68.8% (11)	16
Solduc A1	88.8% (47)	0.0% (0)	11.3% (6)	53
Quin A1	61.6% (45)	2.7% (2)	35.6% (26)	73
Quin A7	50.3% (77)	7.8% (12)	41.8% (64)	153
Quinalt A3	79.8% (178)	9.0% (20)	11.2% (25)	223
Miller 3	86.5% (64)	0.0% (0)	13.5% (10)	74
Miller 4	87.4% (188)	0.0% (0)	12.6% (27)	215
Miller 2	83.0% (39)	0.0% (0)	17.0% (8)	47
Miller 1	89.8% (114)	0.0% (0)	10.2% (13)	127
All Sites	73.9% (921)	3.5% (44)	22.6% (282)	1247

Acoustic Sampling

The majority of calls detected by acoustic sampling were *Myotis sp.* at all sites except Queets A1. The detector at Queets A1 picked up many ultra-sonic sounds that appeared to be bat calls, but were too short to accurately determine the species of the bat that made them. See Appendix 3 for listing of all calls. *Plecotus townsendii* was the only species other than *Myotis sp*. positively identified on several sites.

Discussion

The results of this study verified presence of *M. lucifigus, M. yumanensis, M. volans, M. californicus,* and *P. townsendii* within the Olympic National Park boundary that were also captured in prior studies in 1998 and 1999. Additionally, presence of *M. evotis* was confirmed with positive identification made at the wetter, higher elevation site at Three Lakes. This species is known to inhabit high elevation montane forests in the British Columbia Cascade range (Nagorsen and Brigham 1993), so it is not surprising to see this species here as well in a similar environment. We encountered five specimens at sites Miller H1, Miller H3, and Quinault H4 in which the species could have either been classified as a *M. evotis* or a *M. keenii*, in which case we made no distinction. Four out of five of these specimens had hair samples taken for later laboratory analysis and verification of species identification. While four of these individuals were trapped outside of the Park boundary in Miller Peninsula, we feel it is important to include this information as *M. keenii* is a rare species on the Olympic Peninsula and could establish colonies within the Park as it was captured only 9 km. from the Park boundary. In addition, advance knowledge of this species in the general area is useful when making forest management decisions that could increase the probability of successful colonization in the future, if it does not already exist within the Park. Unfortunately, we were not successful in obtaining a hair sample from the one potential *M. keenii* captured within the Park boundary in the Quinault River drainage.

The species records from the Quinault H4 trap location (see Table 1) shows a proportionally large number of Townsend‘s big-eared bats (*Plecotus Townsendii*). Our data shows evidence of a maternity colony in the area, possibly at the one of the buildings in the Kestner homestead. Many of the captured individuals of this species appeared to be nursing females. Townsend's big-eared bats comprise 25 of the 67 captured animals in the Quinault 4 harp trap.

The two instances of *M. thysanodes,* one at the Miller H4 site and the other at the Queets H2 site is notable. While this species is known to typically inhabit dryer Douglas-fir/Ponderosa pine forests, the distinctive characteristics of this species' fringed outer tail membrane along with the greater weight and forearm and ear length were convincing factors in identifying this species as we did. The individual found in Miller Peninsula inhabited an area that has rainfall (400mm - 500mm average annual precipitation) equivalent to that found in the Ponderosa pine forests of Eastern Washington.

We had originally classified seven of the *M. californicus* as *M. ciliolabrum* based loosely on the range of measurements and pelage, but to a higher degree on the extent of free tail that extended beyond the edge of the uropatagium. Differentiation between these two species is difficult, but this particular morphologic characteristic is much more developed and evident in *M. ciliolabrum*. We recorded the length of free tail, and if greater than 1.5mm, classified it as *M. ciliolabrum* in lieu of *M. californicus*. See Constantine (1998) for a discussion of this method. In the end, however, we could not ignore the arid environment and cliff dwelling behavior this species typically favors and so decided to reclassify these individuals as *M. californicus*. We collected hair samples from three of these specimens for later laboratory analysis and a more definitive decision on classification.

Past studies of bat species present in Olympic National Park completed by Kurt Jenkins, Janet Erickson, and Justin Yeager in 1999 showed a similar composition of species. Direct capture methods revealed the presence of Western long-eared myotis (*Myotis evotis*), Western long-legged myotis (*Myotis volans*), California myotis (*Myotis californicus*), Townsend's Big-eared bat (*Plecotus townsendii*) and little brown myotis/ Yuma myotis (*Myotis lucifugus/yumanensis*). The use of Ultrasonic monitoring also showed the possible presence of Big brown/ silver haired/ hoary bats (*Eptesicus/Lasionycteris/Lasiurus*).

Mean temperatures at recording sites nearest our survey areas all showed positive departure from the 30 year average in both June and July by as much as 3.9°F (Elwha Ranger Station). Conversely, precipitation at these same recording stations showed a negative departure from the 30 year average in both June and July by as much as 2.9 inches (Forks 1E station). These two factors may influence the probability of finding species that are more typically found in warmer, more arid climates. Although, *M. ciliolabrum* and *M. thysanodes* would necessarily be in the general vicinity to detect changes in temperature and precipitation.

Trapping and recording presence of species using the ANABAT ultrasonic detectors in the high elevation, drier moisture gradient sites on Hurricane Ridge and Deer Park came across difficulties. Only a single individual was caught on the Hurricane Ridge and Deer Park trap sites as shown on Table 1. This data may be misleading because of the limitations in sampling these locations. Steep elevation gradients, lack of adequate trapping sites and the malfunctioning of the ANABAT recorders may not have allowed for accurate observations of presence while sampling in these locations.

There were numerous internal failures in the delay switches that resulted in lost sample nights. While faulty batteries were the cause in a few cases, the electronics within the delay switches also failed. We had assembled and tested all of the Anabat systems before use in the field, but this did not prove to be sufficient preparation. As a result, we obtained only a small fraction of echolocation data that would otherwise have been possible with reliable equipment. A repair service for these units was located, but unable to repair the equipment in the short time frame we required.

Literature Cited

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Appendix 1. Bats captured during Olympic National Park survey 2003**.**

	Site Name	Date	Time	Taxon	Sex	Age[1]	Repr[2]	Wt[3]	FA[4]	HF[5]	EL[6]	Keel	Hair Sample
1	Miller H3	6/18/2003	9:56	MYCA	M	A	UC	4	33	5	8	Y	No
2	Miller H3	6/18/2003	10:03	MYVO	F	J	NR	7	38	8	15	Y	No
3	Miller H3	6/18/2003	10:10	MYCA	M	A	UC	4	32	4	9	Y	No
4	Miller H3	6/18/2003	10:22	MYCA	M	A	UC	4	32	5	10	Y	No
5	Miller H3	6/18/2003	10:32	MYCA	F	A	R	6	31	6	8	Y	No
6	Miller H2	6/19/2003	9:07	MYCA	F	A	R	6	31	5	10	Y	No
7	Miller H2	6/19/2003	9:07	MYCA	F	A	R	7	39	7	10	Y	No
8	Miller H2	6/19/2003	9:14	MYCA	F	A	R	5	30	5	9	Y	No
9	Miller H2	6/19/2003	9:14	MYCA	F	J	NR	4	33	5	10	Y	No
10	Miller H2	6/19/2003	9:18	MYCA	F	A	NR	6	29	5	9	Y	No
11	Miller H2	6/19/2003	9:29	MYCA	F	J	NR	6	33	6	10	Y	No
12	Miller H2	6/19/2003	9:29	MYCA	F	A	NR	4	32	5	10	Y	No
13	Miller H3	6/19/2003	10:37	MYEV/KE	M	A	UC	5	36	9	17	N	Yes
14	Miller H3	6/19/2003	10:40	MYEV/KE	F	A	R	6	37	8		N	Yes
15	Miller H3	6/19/2003	10:43	MYCA	M	A	UC	4	30	5	9	Y	No
16	Miller H3	6/19/2003	10:47	MYVO	F	A	R	7	38	8	9	Y	No
17	Miller H3	6/19/2003	10:57	MYCA	F	A	R	6	31	5	9	Y	No
18	Miller H3	6/19/2003	11:00	MYLU	M	A	UC	6	40	10	9	N	No
19	Miller H3	6/19/2003	11:15	MYEV/KE	F	A	R	7	38	9	17	N	No
20	Miller H3	6/19/2003	11:16	MYCA	M	A	UC	4	32	4	8	Y	No
21	Miller H3	6/19/2003	11:18	MYCA	M	A	UC	4	31	5	11	Y	No
22	Miller H3	6/19/2003	11:20	MYCA	M	A	UC	3	29	5	7	Y	No
23	Miller H3	6/19/2003	11:20	MYCA	M	A	UC	4	31	6	10	Y	No
24	Miller H3	6/19/2003	11:23	MYCA	M	A	UC	4	31	6	11	Y	No
26	Miller H4	6/19/2003	7:40	MYCA	F	A	R	4	32	5	9	Y	No
27	Miller H4	6/19/2003	7:43	MYTH	F	A	R	4	37	9	14	N	No
28	Miller H4	6/19/2003	7:52	MYCA	F	A	R	6	32	6	8	Y	No
29	Miller H4	6/19/2003	7:57	MYCA	F	A	NR	4	30	6	6	Y	No
30	Miller H4	6/19/2003	8:04	MYCA	M	A	UC	4	31	5	9	Y	No
31	Miller H4	6/19/2003	8:07	MYCA	F	A	R	4	32	6	10	Y	No
32	Miller H4	6/19/2003	8:10	MYCA	F	J	NR	4	32	5	9	Y	No
33	Miller H4	6/20/2003	9:21	MYCA	M	A	UC	4	33	6	9	Y	No
34	Miller H4	6/20/2003	9:25	MYCA	M	A	UC	4	31	5	9	Y	No
35	Miller H4	6/20/2003	9:25	MYCA	F	A	NR	4	31	6	10	Y	No

Record ID	Site Name	Date	Time	Taxon	Sex	Age[1]	Repr[2]	Wt[3]	FA[4]	HF[5]	EL[6]	Keel	Hair Sample
36	Miller H4	6/20/2003	9:28	MYCA	F	A	R	6	32	6	9	Y	No
37	Miller H4	6/20/2003	9:30	MYCA	F	A	R	5	32	6	9	Y	No
38	Quinault H1	6/25/2003	8:25	MYYU	M	A	UC	4	33	6	10	N	No
39	Quinault H1	6/25/2003	8:25	MYCA	F	A	NR	5	32	7	7	Y	No
40	Quinault H1	6/25/2003	8:25	MYCA	M	A	UC	4	32	5	11	Y	No
41	Quinault H3	6/26/2003	9:52	MYYU	M	A	UC	4	31	5	9	N	No
42	Quinault H3	6/26/2003	9:52	MYCA	M	A	UC	4	31	5	8	Y	No
43	Quinault H3	6/26/2003	9:54	MYYU	M	A	UC	4	30	5	10	N	No
44	Quinault H3	6/26/2003	9:56	MYCA	M	A	UC	4	29	6	9	Y	No
45	Quinault H3	6/26/2003	10:00	MYYU	F	A	R	5	31	5	10	N	No
46	Quinault H3	6/26/2003	10:07	MYCA	F	A	NR	4	29	5	11	Y	No
47	Quinault H3	6/26/2003	10:10	MYCA	F	A	R	5	32	5	8	Y	No
48	Quinault H4	6/26/2003	7:44	PLTO	F	A	R	14	47	8	32	N	No
49	Quinault H4	6/26/2003	7:48	MYCA	F	A	R	5	31	5	9	Y	No
50	Quinault H4	6/26/2003	7:49	PLTO	F	A	R		46	10		N	No
51	Quinault H4	6/26/2003	7:52	PLTO	F	A	R	11	43	7	34	N	No
52	Quinault H4	6/26/2003	7:57	PLTO	F	A	R	14	46	8	35	N	No
53	Quinault H4	6/26/2003	8:03	PLTO	F	A	NR	12	42	8	33	N	No
54	Quinault H4	6/26/2003	8:06	PLTO	F	A	R		43	7	34	N	No
55	Quinault H4	6/26/2003	8:07	MYLU	F	A	NR	6	35	8	10	N	No
56	Quinault H4	6/26/2003	8:11	PLTO	F	A	R	14	44	8	33	N	No
57	Quinault H4	6/26/2003	8:16	PLTO	F	A	R	14	43	7	33	N	No
58	Quinault H4	6/26/2003	8:17	MYCA	F	A	R	6	32	5	9	Y	No
59	Quinault H4	6/26/2003	8:20	MYCA	F	A	R	5	29	6	9	Y	No
60	Quinault H4	6/26/2003	8:21	MYLU	M	A	UC	6	33	7	10	N	No
61	Quinault H4	6/26/2003	8:24	MYCA	F	A	R	4	31	5	9	Y	No
62	Quinault H4	6/26/2003	8:26	MYLU	M	A	UC	6	33	8	8	N	No
63	Quinault H4	6/26/2003	8:28	MYCA	F	A	R	5	32	5	8	Y	No
64	Quinault H4	6/26/2003	8:30	MYLU	F	A	R	7	34	8	10	N	No
65	Quinault H4	6/26/2003	8:33	MYLU	F	A	R	6	33	8	10	N	No
66	Quinault H4	6/27/2003	7:50	PLTO	F	A	R	16	44	10	32	N	Yes
67	Quinault H4	6/27/2003	7:54	PLTO	M	A	UC	8	41	8	30	N	Yes
68	Quinault H4	6/27/2003	7:57	PLTO	F	A	R	14	45	9	31	N	Yes
69	Quinault H4	6/27/2003	8:00	PLTO	F	A	R	14	44	7	31	N	Yes
70	Quinault H4	6/27/2003	8:04	PLTO	F	A	R	14	43	8	32	N	Yes
71	Quinault H4	6/27/2003	8:07	PLTO	F	A	UC	11	45	7	31	N	Yes

Record ID	Site Name	Date	Time	Taxon	Sex	Age[1]	Repr[2]	Wt[3]	FA[4]	HF[5]	EL[6]	Keel	Hair Sample
72	Quinault H4	6/27/2003	8:10	MYLU	M	A	UC	6	34	8	8	N	Yes
73	Quinault H4	6/27/2003	8:13	MYEV/KE	F	A	R	8	38	7	14	N	Yes
74	Quinault H4	6/27/2003	8:21	MYLU	M	A	UC	6	34	7	10	N	Yes
75	Quinault H4	6/27/2003	8:25	MYLU	M	A	UC	5	34	7	10	N	Yes
76	Quinault H4	6/27/2003	8:29	MYLU	M	A	UC	5	33	7	10	N	Yes
77	Quinault H4	6/27/2003	8:34	MYLU	F	A	R	7	36	8	11	N	Yes
78	Quinault H4	6/27/2003	8:40	MYLU	F	A	R	6	36	7	11	N	Yes
79	Quinault H4	6/27/2003	8:44	MYLU	M	A	UC		34	7	10	N	No
80	Quinault H4	6/27/2003	8:46	MYCA	M	A	UC	4	31	6	10	Y	Yes
81	Quinault H4	6/27/2003	8:51	MYLU	M	A	UC	5	32	8	8	N	Yes
82	Quinault H4	6/27/2003	8:53	MYLU	F	A	R	6	36	8	11	N	Yes
83	Quinault H4	6/27/2003	8:57	MYLU	F	A	NR	6	36	13	11	N	Yes
84	Quinault H4	6/27/2003	9:00	MYCA	F	A	R	6	32	5	9	Y	Yes
85	Quinault H4	6/27/2003	9:03	MYLU	M	A	UC	6	33	7	9	N	No
86	Quinault H4	6/27/2003	9:05	MYLU	M	A	UC	6	33	8	9	N	No
87	Quinault H4	6/27/2003	9:05	MYLU	F	A	R	6	34	8	11	N	No
88	Quinault H4	6/27/2003	9:08	MYCA	F	A	R	6	37	8	16	Y	Yes
89	Quinault H4	6/27/2003	9:10	MYLU	F	A	R	8	35	6	12	N	No
90	Quinault H4	6/27/2003	9:20	MYLU	F	A	R	5	33	8	10	N	No
91	Quinault H4	6/27/2003	9:29	MYLU	M	A	UC	5	35	8	10	N	No
92	Quinault H4	6/27/2003	9:30	MYLU	F	A	NR	6	35	6	9	N	No
93	Quinault H4	6/27/2003	9:33	MYLU	F	A	R	6	36	8	12	N	No
94	Quinault H4	6/27/2003	9:34	MYLU	F	A	R	8	37	9	12	N	No
95	Quinault H4	6/27/2003	9:37	MYLU	M	A	UC	4	33	6	9	N	No
96	Quinault H4	6/27/2003	9:38	MYLU	M	A	UC	4	34	9	9	N	No
97	Quinault H4	6/27/2003	9:39	MYLU	UC	UC	UC		34		9	N	No
98	Quinault H4	6/27/2003	9:42	MYLU	F	A	NR	5	33	7	10	N	No
99	Quinault H4	6/27/2003	9:43	MYCA	M	A	UC	4	31	6	7	Y	Yes
100	Quinault H4	6/27/2003	9:46	MYLU	F	A	R	6	33	8	9	N	No
101	Quinault H4	6/27/2003	9:47	MYLU	F	A	R	6	35	7	11	N	No
102	Quinault H4	6/27/2003	9:49	MYLU	M	A	UC	4	33	8	9	N	No
103	Quinault H4	6/27/2003	9:50	MYCA	M	A	UC	4	31	6	8	Y	Yes
106	Sol Duc H1	6/29/2003	7:06	MYCA	M	A	UC	4	31	4	10	Y	Yes
107	Sol Duc H1	6/29/2003	7:12	MYCA	F	A	R	4	31	5	10	Y	No
108	Sol Duc H2	6/29/2003	7:38	MYCA	M	A	UC	4	33	6	10	Y	No

Record ID	Site Name	Date	Time	Taxon	Sex	Age[1]	Repr[2]	Wt[3]	FA[4]	HF[5]	EL[6]	Keel	Hair Sample
109	Sol Duc H2	6/29/2003	7:45	MYEV	F	A	R	6	39	8	15	Y	No
110	Sol Duc H2	6/30/2003	8:15	MYLU	F	A	R	6	35	8	11	N	No
111	Sol Duc H3	6/30/2003	7:30	MYCA	F	A	R	5	33	6	9	Y	No
112	Sol Duc H4	6/30/2003	7:00	MYCA	F	A	R	6	32	5	9	Y	Yes
113	Sol Duc H1	7/1/2003	7:30	MYCA	F	A	R	6	31	5	11	Y	No
114	Sol Duc H2	7/1/2003	8:30	MYLU	F	A	NR	5	36	7	11	N	No
115	Sol Duc H3	7/1/2003	7:45	MYLU	M	A	UC	5	33	8	10	N	No
116	Elwha H3	7/2/2003	8:07	MYCA	F	A	R	4	31	5	10	Y	Yes
117	Elwha H3	7/2/2003	8:10	MYCA	F	A	R	5	32	5	9	Y	Yes
118	Elwha H3	7/2/2003	8:13	MYCA	F	A	R	6	33	6	10	Y	Yes
119	Elwha H3	7/2/2003	8:17	MYYU	M	A	UC	5	31	5	10	N	Yes
120	Elwha H3	7/2/2003	8:17	MYCA	F	A	R	4	31	5	10	Y	No
121	Elwha H1	7/2/2003	6:48	MYCA	F	A	R	4	32	5	10	Y	Yes
122	Elwha H1	7/2/2003	7:00	MYCA	F	A	R	4	31	5	10	Y	Yes
123	Elwha H1	7/2/2003	7:02	MYCA	M	A	UC	4	31	7	9	Y	Yes
124	Elwha H1	7/2/2003	7:06	MYCA	M	A	UC	4	30	5	9	Y	Yes
125	Elwha H4B	7/3/2003	8:43	MYCA	F	A	R	5	32	5	7	Y	No
126	Elwha H3	7/3/2003	7:15	MYYU	F	A	NR	3	32	6	9	N	Yes
127	Elwha H3	7/3/2003	7:15	MYCA	F	A	R	5	31	4	9	N	Yes
128	Quinault H3	7/8/2003	9:30	MYCA	M	A	R	5	31	6	11	Y	No
129	Quinault H3	7/8/2003	9:30	MYCA	F	A	R	5	31	6	11	Y	No
130	Quinault H3	7/8/2003	9:38	MYCA	F	A	NR	4	32	6	10	N	Yes
131	Quinault H3	7/8/2003	9:38	MYCA	M	A	UC	5	33	5	10	Y	No
132	Quinault H3	7/8/2003	9:40	MYCA	F	A	R	6	32	6	10	Y	No
133	Quinault H3	7/8/2003	9:44	MYYU	M	A	UC	4	31	5	9	N	No
134	Quinault H3	7/8/2003	9:45	MYCA	M	A	UC	5	31	5	11	Y	No
135	Quinault H4	7/8/2003	8:17	PLTO	F	A	R	12	44	9	32	N	Yes
136	Quinault H4	7/8/2003	8:17	PLTO	F	A	R	11	42	10	32	N	Yes
137	Quinault H4	7/8/2003	8:22	PLTO	F	A	R	13	45	10	33	N	Yes
138	Quinault H4	7/8/2003	8:24	PLTO	F	A	R	13	45	10	32	N	Yes
139	Quinault H4	7/8/2003	8:28	PLTO	F	A	R	12	43	8	33	N	No
140	Quinault H4	7/8/2003	8:31	PLTO	F	A	R	10	44	9	33	N	No
141	Quinault H4	7/8/2003	8:31	PLTO	F	A	R	12	44	9	31	N	No
142	Quinault H4	7/9/2003	7:29	PLTO	F	A	R	8	45	9	32	N	No
143	Quinault H4	7/9/2003	7:30	PLTO	F	A	R	12	43	8	31	N	No

Record ID	Site Name	Date	Time	Taxon	Sex	Age[1]	Repr[2]	Wt[3]	FA[4]	HF[5]	EL[6]	Keel	Hair Sample
144	Quinault H4	7/9/2003	7:36	PLTO	F	A	R	10	45	8	33	N	No
145	Quinault H4	7/9/2003	7:40	PLTO	F	A	R	11	45	8	33	N	No
146	3 Lakes H2B	7/12/2003	8:07	MYLU	F	A	NR	6	32	8	9	N	No
147	3 H2B	7/12/2003	8:14	MYEV	M	A	UC	5	37	9	12	N	No
148	3 H2B	7/12/2003	8:16	MYCA	M	A	UC	4	32	6	10	Y	No
149	Miller H4	7/15/2003	7:41	MYCA	F	A	R	5	32	5	8	Y	No
150	Miller H4	7/15/2003	7:42	MYCA	M	A	UC	4	33	5	9	Y	No
151	Miller H1	7/15/2003	8:29	MYCA	M	A	UC	4	31	5	10	Y	No
152	Miller H1	7/15/2003	8:29	MYCA	M	A	UC	5	32	5	10	Y	No
153	Miller H1	7/15/2003	8:39	MYCA	M	A	UC	5	31	4	10	Y	No
154	Miller H1	7/15/2003	8:40	MYCA	M	A	UC	4	32	5	10	Y	No
155	Miller H3	7/16/2003	7:30	MYCA	M	A	UC	4	30	5	10	Y	No
156	Miller H4	7/16/2003	8:06	MYCA	F	A	R	4	31	6	9	Y	No
157	Miller H1	7/16/2003	9:20	MYCA	F	A	R	4	29	4	8	Y	No
158	Miller H1	7/16/2003	9:22	MYCA	F	A	R	4	33	5	10	Y	Yes
159	Miller H1	7/16/2003	9:30	MYCA	F	A	R	5	32	5	9	Y	No
160	Miller H1	7/16/2003	9:32	MYCA	M	A	UC	4	31	5	9	Y	No
161	Miller H1	7/16/2003	9:35	MYCA	M	A	UC	4	31	2	9	Y	No
162	Miller H1	7/16/2003	9:35	LANO	M	A	UC	11	42	7	11	N	Yes
163	Miller H1	7/16/2003	9:51	EPFU	M	A	UC	21	47	10	15	N	Yes
164	Miller H1	7/16/2003	10:00	MYEV/KE	F	A	NR	5	37	7	18	N	Yes
165	Miller H1	7/16/2003	10:00	MYCA	F	A	R	4	32	5	10	Y	No
166	Miller H1	7/16/2003	10:05	MYCA	M	A	UC	4	30	5	7	Y	No
167	Miller H1	7/16/2003	10:06	MYCA	M	A	UC	5	32	5	9	Y	No
168	Miller H1	7/16/2003	10:07	MYLU	M	A	UC	6	38	6	8	Y	No
169	Miller H1	7/16/2003	10:07	MYCA	M	A	UC	4	30	5	10	Y	No
170	Miller H1	7/16/2003	10:07	MYCA	M	A	UC	4	32	6	8	Y	No
171	Miller H1	7/16/2003	10:15	MYCA	M	A	UC	4	31	5	10	Y	No
172	Miller H1	7/16/2003	10:15	MYCA	F	A	NR	4	31	5	10	Y	No
173	Miller H1	7/16/2003	10:17	MYCA	M	A	UC	4	32	5	7	Y	No
174	Miller H1	7/16/2003	10:18	MYCA	F	A	NR	4	32	4	9	Y	No
175	H. Ridge H2	7/21/2003	10:24	MYCA	F	A	R	5	33	5	10	Y	No
176	Hoh H1	7/23/2003	9:45	MYLU	F	A	R	6	37	7	11	N	No
177	Hoh H1	7/23/2003	9:49	MYLU	M	A	UC	5	35	8	10	N	No
178	Hoh H1	7/23/2003	9:49	MYLU	F	A	NR	4	36	7	13	N	No

Record ID	Site Name	Date	Time	Taxon	Sex	Age[1]	Repr[2]	Wt[3]	FA[4]	HF[5]	EL[6]	Keel	Hair Sample
179	Hoh H1	7/23/2003	9:50	MYLU	M	A	UC	6	36	8	10	N	No
180	Hoh H1	7/23/2003	9:52	MYLU	F	A	NR	6	37	6	11	N	No
181	Hoh H1	7/23/2003	9:56	MYLU	F	A	NR	6	34	6	11	N	No
182	Hoh H1	7/23/2003	9:57	MYLU	M	A	UC	6	36	8	11	N	No
183	Hoh H1	7/23/2003	10:00	MYCA	M	A	UC	4	34	5	11	Y	No
184	Queets H2	7/24/2003	9:07	MYCA	F	A	R	6	33	5	10	Y	No
185	Queets H2	7/24/2003	9:10	MYCA	F	A	R	5	32	5	10	Y	No
186	Hoh H1	7/24/2003	9:42	MYCA	F	A	R	8	33	7	10	Y	No
187	Hoh H1	7/24/2003	9:45	MYLU	F	J	NR	6	34	8	10	N	No
188	Hoh H1	7/24/2003	9:50	MYLU	F	A	NR	5	36	7	11	N	No
189	Hoh H1	7/24/2003	9:52	MYLU/YU	M	J	UC	6	34	8	11	N	No
190	Hoh H1	7/24/2003	9:52	MYCA	F	A	R	4	32	5	10	Y	No
191	Hoh H1	7/24/2003	9:55	MYLU/YU	M	A	UC	5	33	8	9	N	No
192	Hoh H1	7/24/2003	10:00	MYYU	M	A	UC	5	34	7	11	N	No
193	Queets H2	7/25/2003	8:10	MYTH	F	A	R	7	39	7	16	N	No
194	Queets H2	7/25/2003	8:10	MYCA	M	J	UC	4	31	6	8	Y	No
195	Hoh H1	7/25/2003	7:58	MYLU	M	A	UC	6	36	9	11	N	No
196	Hoh H1	7/25/2003	8:05	MYCA	M	A	UC	5	32	5	10	Y	No
197	Hoh H1	7/25/2003	8:07	MYLU	M	A	UC	6	34	7	11	N	No
198	Hoh H1	7/25/2003	8:10	MYCA	M	A	UC	5	32	5	10	Y	No
199	Hoh H1	7/25/2003	8:18	MYLU	M	A	UC	6	35	8	9	N	No
200	Hoh H1	7/25/2003	8:20	MYCA	F	A	R	5	32	5	10	Y	No
201	Hoh H1	7/25/2003	8:25	MYLU	M	A	UC	7	37	7	13	N	No
202	Hoh H1	7/25/2003	8:25	MYCA	F	A	R	6	32	5	10	Y	No
203	Hoh H1	7/25/2003	8:30	MYLU/YU	M	A	UC	6	35	8	11	N	No
204	Hoh H1	7/26/2003	10:27	MYLU	F	A	R	6	35	8	11	N	No
205	Hoh H1	7/26/2003	10:30	MYLU	M		UC	4	34	7	10	N	No
206	Hoh H1	7/26/2003	10:32	MYLU	F	A	NR	6	36	7	11	N	No
207	Hoh H1	7/26/2003	10:35	MYLU	M	A	UC	5	35	8	10	N	No
208	Hoh H1	7/26/2003	10:37	MYLU	F	A	R	6	37	8	12	N	No
209	Hoh H1	7/26/2003	10:40	MYCA	M	A	UC	4	32	6	11	Y	No
210	Hoh H1	7/26/2003	10:42	MYCA	F	A	R	4	31	5	10	Y	No
211	Hoh H1	7/26/2003	10:47	MYLU	M	A	UC	5	36	7	11	N	No
212	Hoh H1	7/26/2003	10:49	MYLU	M	A	UC	6	37	7	11	N	No
213	Hoh H1	7/26/2003	10:50	MYLU	M	A	UC	6	36	8	12	N	No

Record ID	Site Name	Date	Time	Taxon	Sex	Age[1]	Repr[2]	Wt[3]	FA[4]	HF[5]	EL[6]	Keel	Hair Sample
214	Hoh H1	7/26/2003	10:58	MYYU	F	A	R	6	36	7	10	N	No
215	Hoh H1	7/26/2003	11:00	MYLU	M	A	UC	5	34	8	11	N	No
216	Hoh H1	7/26/2003	11:03	MYLU	M	A	UC	5	33	6	9	N	No
217	Hoh H1	7/26/2003	11:06	MYLU	M	A	UC	5	35	8	11	N	No
218	Ozette H1	8/1/2003	8:00	MYCA	M	A	UC	5	31	5	10	Y	No
219	Ozette H1	7/31/2003	7:35	MYCA	M	A	UC	5	30	5	9	Y	No
220	Ozette H1	7/31/2003	7:40	MYLU/YU	F	A	R	8	38	7	10	Y	No
221	Ozette H1	7/31/2003	7:43	MYCA	M	J	UC	4	30	4	9	Y	No
222	Ozette H1	7/31/2003	7:48	MYCA	M	J	UC	4	31	5	10	Y	No
223	Ozette H1	7/31/2003	7:53	MYCA	M	A	UC	4	33	4	11	Y	No
224	Ozette H1	8/2/2003	7:28	MYCA	M	A	UC	5	31	5	10	Y	No
225	Ozette H1	8/2/2003	7:30	MYYU	M	A	UC	7	35	7	10	N	No
226	Ozette H1	8/2/2003	7:31	MYCA	M	A	UC	4	28	6	8	Y	No
227	Ozette H1	8/2/2003	7:32	MYCA	F	A	R	6	32	6	7	Y	No
228	Ozette H1	8/3/2003	7:45	MYLU	F	A	NR	6	36	8	11	N	No
229	Ozette H1	8/3/2003	7:49	MYCA	M	A	UC	4	31	5	10	Y	No
230	Ozette H1	8/3/2003	7:51	MYCA	M	A	UC	4	30	5	8	Y	No
231	Ozette H1	8/3/2003	7:54	MYCA	M	A	UC	4	31	4	10	Y	No
232	Ozette H1	8/3/2003	7:55	MYCA	F	A	NR	4	30	5	9	Y	No
233	Solduc A2	6/29/2003	22:22	MYEV/KE	UC		UC					UC	No
234	Queets H1	6/28/2003	7:30	MYLU	F	A	R	6	36	9	11	N	No
235	Queets H1	6/28/2003	7:35	MYCA	F	A	R	5	31	5	10	Y	Yes
104*	Queets H2	6/28/2003	7:30	MYLU	F	A	R	6	36	9	11	N	No
105*	Queets H2	6/28/2003	7:35	MYCA	F	A	R	5	31	5	10	Y	Yes

Notes

*	Data incorrectly entered at location Queets H2, subsequently entered as record IDs 234 and 235.
1	A = adult, J= juvenile
2	R = reproductive, NR = non-reproductive, UC = unclassified
3	Wt = grams
4	FA = Forearm length
5	HF = Hind foot length
6	EL = ear length

Appendix 2. Elizabeth Bickford. Segregation of male and female Vespertilionid bats by elevation on the Olympic Peninsula. Bachelor of Science Thesis.

Segregation of Male and Female Vespertilionid Bats by Elevation on the Olympic Peninsula, Washington

By

Elizabeth Mary Bickford

A senior thesis submitted in partial fulfillment
of the requirements for the degree of

Bachelor of Science

Wildlife Science Program
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2003

Approved by ______________________________

Faculty Thesis Supervisor

Date ____________________

Abstract:

It is proposed that bats in western Washington are distributed along an elevational gradient with males and non-reproductive females occupying the higher elevation sites (between 800 and 1300 meters above sea level) and reproductive females occupying the lower elevation sites (below 150 meters above sea level). To test this assumption I performed a field study in the Olympic National Park using Tuttle traps and mist nets to live capture and identify bats to species and determine sex. Little is known about the species on the Olympic Peninsula due to the lack of previous studies. This study is part of a larger study funded by the National Parks Service. The objective of the overall study was to verify a bat species list within the park. Four study areas were used with four trap sites in each and they were open for four nights each except one area which had only three sites and traps there were open for three nights each. Traps were checked in the morning and data from collected bats was recorded. An insufficient number of bats of any species were trapped in the high elevation sites to test the data statistically for the original hypothesis. Instead, data were statistically analyzed to test the hypotheses that there are an equal number of bats of each species on the west side as the east and that species richness is the same from the west to the east side. Neither hypothesis was rejected.

Introduction:

Bat species have different resource requirements at different life stages as do males and females of a given species. Different requirements cause these male and female bats to be located heterogeneously across the landscape. They may sort themselves out along many gradients including temperature, elevation, climate, and resource type and availability (Grindel 1992). Bats of many species are believed to be segregated by sex along an elevation gradient with reproductively active females occupying the lower elevation sites and the males and non-reproductive females occupying the higher elevation sites. Of all the groups, reproductively active females' requirements are the largest. Breeding females require huge amounts of energy to produce young (Nagorsen and Brigham 1993, Henry et al. 2002, Wilkinson and Barclay 1997, Grindel 1992). Gestation, lactation, and providing for a weaned young are very energy consuming. Bats are income breeders and must therefore cover the costs of breeding with daily intake of nourishment (Henry et al. 2002). Breeding females consume approximately their weight in insect matter each night (Nagorsen and Brigham 1993). Caring for these young is the sole responsibility of the mother (Nagorsen and Brigham 1993).

The energy requirements of males and non-reproductive females are far less than those of breeding females (Grindel et al. 1999, Cryan et al. 2000, Nagorsen and Brigham 1993, Wilkinson and Barclay 1997). Males are typically found to forage over larger geographic areas than females of the same species (Cryan et al. 2000). It has been suggested that since males use lower quality sites and are not tied to one roost, they range all over in their foraging (Wilkinson 1997, van Zyll de Jong 1985). During the non-breeding season, males generally keep themselves separate from the females (Petzsch 2000). The bats of the Olympic Peninsula typically do not breed until their second summer (Nagorsen and Brigham 1993). These 1year-old females will probably follow the same foraging patterns as the males, because they do not have a young in a roost which they must tend to.

The bat species of the Olympic Peninsula all belong to the insectivorous family Vespertilionidae (Ingles 1965). They are therefore only active when and where insects are available. Insects are found in small quantities at higher elevations due to cooler temperatures (Nagorsen and Brigham 1993, Cryan et al. 2000). Lower elevation is better habitat for insects and therefore bats.

To conserve energy, bats may go into torpor at night where body temperature drops to a few degrees above the environmental temperature (Drickhamer and Feldhammer 1999, Petzsch 2000). Female bats try to avoid going into torpor if at all possible, because this can lengthen gestation (Nagorsen and Brigham 1993, Wilkinson and Barclay 1997, Cryan et al. 2000). At higher elevations, the night time temperatures can go as low as 0 C° even in the summer (Whitney 1983, McNulty 1996), which could significantly lengthen pregnancy (Nagorsen and Brigham 1993, Petzsch 2000). Females can decrease the length of gestation by choosing roosts in areas with higher temperatures (Racey 1973). Because males can go into torpor at any time, they are able to roost and live in the higher elevation sites (Wilkinson and Barclay 1997). Roost sites are also of specific importance for bats of the Olympic Peninsula because of the effect of roost quality on the quality of young produced. Mortality among bats is highest during the first winter (van Zyll de Jong 1985); young who are born later in the summer are less fit for surviving the coming winter (Grindel et al. 1999). Warmer temperatures help in the development of young bats (Henry et al. 2002, Nagorsen and Brigham 1993). Reproductively active females therefore choose nesting roosts which are several degrees warmer than if they were not raising young (Nagorsen and Brigham 1993). They also choose roosting sites close to foraging areas because when lactating, they often return during the night to nurse their young (Henry et al. 2002).

Similar studies have been performed in other areas of the world, including Italy (Russo 2002), southern British Columbia (Grindel et al. 1999), and North Dakota (Cryan et al. 2000), testing bat distribution along an elevation gradient. These three studies found a significant difference in elevation at which the sexes were found with the males in the high elevation and females in the low. Due to the variability of behavior between many species and between geographically separated subgroups of species, it is inappropriate to presume the behavior of one species based on that of another. Therefore, it is important to learn about the specific activities of bats in each area, including the Olympic Peninsula.

This study is part of a larger survey funded by the National Park Service entitled “Bat Inventory of Olympic National Park”. In 1998 the National Parks Omnibus Act was enacted and mandated that the resources of the National Parks be inventoried. A species list for each taxonomic group has been completed for many of the vertebrates and vascular plants of Olympic National Park. The bats have not yet had a verification of 90% for their species list.

Four study areas were used: Miller’s Peninsula State Park (low/dry), Hurricane Ridge/Deer Park Area (high/dry), Quinalt River Basin (low/wet), and Three Lakes (high/wet). Each of these study areas had four traps at four separate sites which were open for 4 nights, with the exception of Three Lakes which only had three traps each open for 3 nights. Only harp traps were employed in this study with the exception of one site at Three Lakes. Traps were checked in the mornings and data from trapped bats were recorded. Ten species of bats were trapped including*: Myotis californicus, Myotis yumanensis, Myotis evotis, Myotis lucifugus, Myotis keenii, Myotis thysanodes, Myotis volans, Lasionycteris noctivagans, Eptesicus fuscus,* and *Plecotus townsendii*. A total of 143 bats from ten species were trapped in the low elevation with 61 on the dry, east side and 81 on the wet, west side of the peninsula. Four bats from three species were trapped in the high elevation with one from the dry side and three from the wet side. Insufficient bats were collected in these high elevation sites to statistically analyze the data for the proposed hypothesis that reproductively active females occupy the low elevation sites (below 150 meters) and males and non-reproductive females occupy the higher elevation sites (between 800 and 1300 meters above sea level). Instead, the data were analyzed for quantity per species for the California myotis and little brown myotis and species richness compared between the lower elevation sites of the wet and dry sides.

Methods:

Study Area

The Olympic National Park is situated in the middle of the Olympic Peninsula in Washington, covering almost 5000 km^2 (Whitney 1983, McNulty 1996). The park consists mostly of mountains, but also encompasses a long narrow strip of low land along the Pacific coast (McNulty 1996). Within these mountains, no peak is more than thirty miles from salt water (Whitney 1983). From sea level to the top of Mt. Olympus, the highest peak in the Olympic Mountains is a sharp elevation gradient, with an elevation gain of 2428 m (Whitney 1983). This region receives extremely variant amounts of rainfall with less than fifty-one centimeters a year in the rain shadow of the Olympic Mountains to more than 500 cm a year in the Hoh rainforest (Whitney 1983, McNulty 1996). As a result of this climate range, there is an observable change in the flora and fauna from the west to the east side (McNulty 1996).

Site Descriptions

<u>Miller's Peninsula State Park</u>

This park is a newly acquired piece of state owned land, not yet open to the public. Most of the 280 ha park has been logged within the last 20 to 70 years, leaving relatively young, dense stands. Fire and wind have also had effect in shaping the stand dynamics of these forests. *Psuedotsuga menziesii* is the dominant tree species of this area, but some *Thuja plicata* and *Arbutus menziesii* are dispersed throughout. The understory consists mostly of *Holodiscus discolor, Gaultheria shallon,* and *Rhododendron macrophyllum*. Three trap sites in this area were set along forest trails and one was set along a wetland with no standing water. Elevations of these trap sites varied between 30 and 90 m above sea level. This area is very dry, receiving less than 50 cm of rain annually and is the low/dry component of the study. Although this area is not within the national park boundaries, it was included in this study because no suitable sites under 900 m were available in the park on the dry side.

Deer Park/Hurricane Ridge Areas

This area is dominated by western redcedar, douglas-fir, and *Abies amabilis* with salal and *Vaccinium ovalifolium* between 800 and 1300 m above sea level and *Abies lasiocarpa* and *Chamaecyparis nootkatensis* in the high site (1300 m). These areas constitute the high/dry component of this study. Traps were placed along trails near streams. These areas are also in the rain shadow of the Olympic Mountains and receive minimal amounts of rain per year. Mostly old growth forest blankets these slopes, but one trap site (HURR H1) was placed in a relatively young forested area. A fire in 1898 wiped out the vegetation around the Lake Angeles area.

Quinalt River Drainage

The Quinalt River basin is dominated by old growth *Picea sitchensis* and western redcedar. The understory consists mostly of *Polystichum munitum* and *Rubus spectabilis*. The forest structure is very open below with a closed canopy above. Some wetlands and meadows are dispersed throughout. Situated on the south west edge of the peninsula, this area can receive up to 500 cm of rain per year and is therefore the low/wet elevation component of the study. No trap site exceeded 140 m above sea level. Traps were placed in riparian areas, wetlands and one at the forest-meadow interface along the trail leading to Kestner Homestead. The Townsend’s Big-eared bats prefer buildings and structures for roost sites. A large number of these bats were trapped at this site. This is probably due to the abandoned farmstead close by providing excellent roostage. One Townsend’s Big-eared bat was observed roosting in the old smoke house.

Three Lakes Area

Although not exceeding 1000 m in elevation, this site had a sub-alpine feel to it. Two shallow muddy lakes were surrounded by *Carex nigricans* and then green meadow. Trees were found in clumps, but the groupings were dispersed sparsely across the landscape. The dominant trees are Alaska yellow cedar and sub-alpine fir with some *Tsuga mertensiana*. The understory is oval-leafed blueberry and *Xenophyllum tenax*. This area constitutes the high/wet aspect of the study. Trap sites were openings in the somewhat denser forest behind the lakes to the lakes/meadows. The one mist net site was at the south end of the biggest lake.

Field Methods

All data for this study came from the live capture of bats in June and July of 2003. Four areas with four traps sites each were used with the exception of Three Lakes which had only three sites. Trap sites were spaced at least 0.8 km apart making them separate replicates within each area. Each trap was open for 4 nights equaling 16 trap nights per area. The traps at Three Lakes were open for 3 nights equaling 9 trap nights. Total trap nights for the entire project was 57. To account for the study being confounded by time and/or seasonal variation in bat activity, traps were supposed to be open for 2 nights in each area and then moved to another area for 2 nights and so on. Unfortunately weather had a serious effect on how trap nights were dispersed between the areas. The trap nights at Three Lakes were completed in 3 consecutive nights due to the difficulty in reaching the study area with all necessary gear. Hurricane Ridge also was trapped for the full 4 nights consecutively due to weather constraints. The 4 trap nights at the Quinalt River basin and Miller's Peninsula State Park were arranged with 2 nights early in the season and then 2 later.

Traps were checked in the mornings starting at 6:30 am. Data for collected bats were recorded for time of capture/processing, species, sex, age, reproductive status (females only), presence/absence of a keel, forearm length, ear length, hind foot length, and sometimes hair samples for the Park. The Park had several requirements for the overall project including that DNA samples be taken from ten specimens of each species caught. Hair samples were removed from the specimens using tweezers. Approximately 10 hairs with root attached were removed and placed in a test tube filled with alcohol. Each test tube was marked with date and place of capture, species, and observation number corresponding to the data sheet on which the specimen's information was entered.

Due to the absolute lack of success with mist nets early on in the project, they were not employed in this study, except at Three Lakes due to previously stated reasons where they were also not successful in trapping a bat specimen. Harp traps, or more commonly known as Tuttle traps, proved to be the more adequate means for catching bats. Ten, possibly eleven species were caught using this method. Both methods create their own species bias. For the testing of the proposed hypothesis of sexual segregation, a sub-set of the actual species present in Olympic National Park were to be tested or rather those that were present in a large enough number to complete statistical analysis on. For the testing of the original hypothesis of sexual segregation, it was therefore irrelevant whether all species were present. For the overall Park's survey species presence was of utmost importance, so other trapping and detecting methods were employed at other sites not included in those used for this aspect of the study.

Analytical Methods

The original hypothesis of sexual segregation along an elevation gradient could not be tested statistically due to lack of data in the high elevation. Since good data were available for the low elevation sites, species richness and quantity of bats per species were compared between the east, dry site (Miller's Peninsula State Park) and the wet, west site (Quinalt River Basin). For species richness, each trap site was treated as a replicate with four replicates total for each area. A two way t-test at $\alpha = 0.05$ was performed to test the hypothesis that there is a different number of species at the two sites, Miller's Peninsula State Park and Quinalt River Basin. For the comparison of quantity of bats per species, a t-test at alpha level of 0.05 was also performed, but the data was first log transformed using the natural log (Zar 1999).

Results

An insufficient number of bats were caught at the high elevation sites to significantly determine the validity of the hypothesis that female bats of the Olympic Peninsula reside in the low elevation sites (below 300 m above sea level) and that male and non-reproductive females are found in the higher elevations (above 900 m above sea level) (tables 2 and 4). Although from viewing the data, one can see that the low elevation sites yielded an approximately equal number of males as females for the California myotis and the little brown myotis (tables 1 and 3).

More species were found at Miller's Peninsula State Park than at the Quinalt River basin (tables 1 and 3), but when tested using a two way t-test at the 0.05 alpha level the difference was not found to be significant ($t_{obs} = 0.899$, $t_{.05(2),3} = 2.447$, p-value > 0.40). Only California myotis were trapped in every area (tables 1, 2, 3, and 4) and the little brown myotis was found in all areas except Deer Park/Hurricane Ridge areas (tables 1, 3, and 4). These two species were therefore the only ones on which statistical analysis could be performed testing whether there was a difference in quantity of bats between the two areas, wet and dry. The two way t-test at the 0.05 alpha level was also not found to be significant for either California myotis ($t_{obs} = 1.88$, $t_{.05(2),6} = 2.447$, p-value > .10) or the little brown myotis ($t_{obs} = 0.58$, $t_{.05(2),3} = 3.18$, p-value > 0.6).

Table 1: Number of bats per sex/reproductive group caught per species at Miller's Peninsula State Park

Species	Reproductive ♀	Non-reproductive ♀	♂	Total for Species
Myotis californicus	16	9	26	51
Myotis evotis	1	2	0	3
Myotis lucifugus	0	0	2	2
Myotis thysonodes	1	0	0	1
Myotis volans	1	0	0	1
Myotis keenii	1	0	1	2
Lasionycteris noctivagans	0	0	1	1
Eptesicus fuscus	0	0	1	1
Total for sex group	20	11	31	62

Table 2: Number of bats per sex/reproductive group caught per species at Hurricane Ridge/Deer Park Areas

Species	Reproductive ♀	Non-reproductive ♀	♂	Total for Species
Myotis californicus	1	0	0	1
Total for sex group	1	0	0	1

Table 3: Number of bats per sex/reproductive group caught per species at the Quinalt River Drainage

Species	Reproductive ♀	Non-reproductive ♀	♂	Total for Species
Myotis californicus	9	3	9	21
Myotis lucifugus	13	3	15	31
Myotis yumanensis	1	0	3	4
Plecotus townsendii	23	1	1	25
Total for sex group	46	7	28	81

Table 4: Number of bats per sex/reproductive group caught per species at Three Lakes

Species	Reproductive ♀	Non-reproductive ♀	♂	Total for Species
Myotis californicus	0	0	1	1
Myotis lucifugus	0	1	0	1
Myotis evotis	0	0	1	1
Total for sex group	0	1	2	3

Discussion:

Many more bats were trapped in the low elevation sites than the high, because these areas are more productive and can support a larger population of bats than the high elevation sites. Nightly temperatures do not drop as low at lower elevations allowing for a greater abundance of insects and therefore bats. Female bats need warm roosts for rearing young. More insects and warmer nights and roosts, which is attractive to breeding females is also attractive to males and non-reproductive females. There are probably enough resources available at these highly productive low elevation sites to support a substantial breeding female population as well as the males and non-reproductive females. Another reason for the concentration of bats in the low elevation is that bats tend to center their activity around water because it supports a greater abundance of insects than the surrounding land as well as provides low resistance flight paths for foraging, drinking, and movement. The high elevation areas in the park are very steep and do not allow much water to collect. This may inhibit the insect population and therefore the bat abundance. It has also been suggested that later in the season, August and September, the bats may move to higher elevations. It could have been too early for the bats to be active during the time of trapping (June and July).

There was an equal number of California myotis and little brown myotis found on the east side of the peninsula as the west side. This means that they are approximately evenly distributed across the landscape at the low elevations. Species richness was also found to be statistically equal. There were different species caught on the west side than the east side of the peninsula, but about the same numbers were found in both areas.

Early in the season it was difficult to decipher if the females were pregnant. Females typically give birth around mid to end of July with gestation lasting around one month (Nagorsen and Brigham 1993). In June, the fetuses were still relatively early in their development and small. To our inexperienced hands, palpitations of the females' abdomens often yielded a non reproductive status. There may have been some falsely determined reproductive statuses early on as well as throughout the study. Species was also difficult to determine in the beginning due to lack of experience. Species such as the fringed bat were most likely misidentified. *Myotis septentrionalis* and *Myotis ciliolabrum* were both identified as being present in the study, but after consulting a range map, it was determined that these were misidentifications because these bats are not found in western Washington. They were re-identified as Keen myotis and california myotis, respectively.

The proposed plan for the study changed some throughout the data collection process due to unforeseen difficulties. For Deer Park/Hurricane Ridge areas the proposed plan had been to use trap sites between 900 and 1200 m in elevation. These elevation parameters, and not higher, were chosen because the high/wet elevation component at Three Lakes does not exceed 1000 m in elevation. It was felt that trapping higher on the dry east side would confound the study by adding another variable (elevation variation). However, due to the difficulty in locating good trap sites, some sites fell above and below the 900 to 1200-m boundary, 800 and 1300 m respectively. Another change occurred in the low/dry areas. It had been planned to use the Audubon Society land at Railroad Bridge Park, but in the preliminary trapping no bats were caught and almost none were detected with Anabat detectors so it was decided not to use this area. The captured bats were also supposed to be marked with a black felt pen to prevent one bat being counted as more than one if captured several nights consecutively. They were not marked and some bats were probably counted more as more than one bat. Bats were not marked because it was felt that the marks would not last long enough to make it worthwhile.

For the live trapping of bats, competing methods exist: mist nets and harp traps (Bookhout 1996). Mist nets are very fine, lightweight nets that are supported by 6-m tall poles. The nets are about 9 m long and 4 m tall and are typically set over rivers, meadows or lakes. They are very portable and convenient, but when set up must be under constant watch for bats (or even birds) flying into them. Bats removed from mist nets are typically agitated and difficult to handle, causing possible damage to the nets, themselves, and the researchers. Harp traps are smaller than mist nets, about 3 m tall by 1.5 m wide. A double set of lengthwise strung 8-pound test fishing lines snare bats as they attempt to fly through the trap. Ensnared bats slide down into the bag hanging under the harp like part of the trap where they roost under the plastic flaps of the canvas bag (see picture 1). Due to their smaller size, these traps must be carefully placed in the flight paths of bats to be successful. Harp traps are set up in the evening and checked in the morning at the convenience of the researcher.

Little is known about the bats of the Olympic Peninsula, due to the lack of completed research. Because knowledge of bat ecology is important for the conservation of these species, it is vital that research into the bat populations of the Olympic Peninsula continues. Females are important to conservation in that they are the ones actually producing new members of the population. Since the bats of interest in this study do not pair bond, fewer males are needed than females to sustain a population. In that case, it would be valuable to focus conservation efforts on lower elevation sites where the reproducing females are found. Low elevation sites are home to both sexes of bats, more so than the higher elevations. These sites are therefore of even greater importance for conservation, because they support most of the bat population.

Acknowledgements:

I would like to thank my co-workers on this study, Patrick Adam and Filip Tkaczyk without whom the fieldwork for this project could not have proceeded. Thanks to Nick Noe for the great pictures of the bats and trap sites. Shelley Hall, our Olympic National Park coordinator was of great assistance in helping us work with the park and meet our needs, thank you. Thanks to Professor Stephen West for giving me the opportunity to work on this project and for supplying equipment and advice.

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Appendix 3. Michelle Noe. Precipitation Gradient and its Effect on Species Composition and Sex Ratios. Bachelor of Science Thesis.

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WILDLIFE SENIOR THESIS
ESC 496

TO:	Stephen D. West
TITLE OF PROJECT:	Precipitation Gradient and its Effect on Species Composition and Sex Ratios
STUDENT'S NAME:	Michelle L. Noe
PERIOD OF RESEARCH:	May 10, 2003 – August, 2003
DATE OF DRAFT:	December 17, 2003

Student's Signature

Abstract

Eleven of the 16 species of bats detected in Washington state may be present within Olympic National Park. The objective of this study is to observe species composition and sex ratios within species at the extremes of the precipitation gradient in Olympic National Park and the surrounding area. Great precipitation, elevation, and habitat gradients occur in the park , making Olympic National Park a good place to observe differences in species composition and sex ratios. The low/wet sites of this study were near Quinault Lake in the southern part of Olympic National Park, northwest of the town of Quinault, and the low/dry sites were in Miller Peninsula State Park which is west of Sequim across Sequim Bay. We used Tuttle traps to collect capture and species presence data during the sampling period of June and July 2003. *Eptesicus fuscus, Lasionycteris noctivagans,* and *Myotis thysanodes* were found only on the dry side. *Plecotus townsendii* was found only on the wet side. *Myotis californicus* was the most abundant species on both sides of the park. Precipitation appeared to only affect species presence and not sex ratios, as sex ratios were not skewed on either side of the park.

Introduction

Bats are second only to rodents in species richness among mammals. Their range spans the globe, excluding the harsh environments of Antarctica and extreme deserts. The 750 species of Microchiroptera are able to take advantage of nearly every habitat on earth due to their wide range of diets which include insects, blood, fruit, flowers and pollen (Schnitzler and Kalko, 2001). Though they range across the globe, relatively little is known about them. Current research is beginning to shed light on their habitat needs and the ways in which they can be preserved in the ever changing environments in which they have historically inhabited and in which humans are now a major source of change.

In western Washington the main threat to bats and bat habitat is habitat conversion to non-forest uses (Stephen West, personal communication). Not enough is known to determine how deforestation and silvicultural practices truly affect bats. Large trees are needed by bats to roost, but open areas are necessary for foraging (Erickson, 1998). The extremes to which humans can alter habitats without harming bats needs to be determined. Several of the bat species in Washington state are in trouble and are either listed or are on their way to being listed on the Endangered Species list. *Myotis thysanodes, Myotis evotis, Myotis volans, Myotis ciliolabrum,* *Coryhorhirus townsendii*, and *Myotis yumanensis* are listed as federal species of concern (WDFW, 2003). *Myotis thysanodes*, *Myotis evotis, Myotis volans, Myotis ciliolabrum, Euderma maculatum* and *Pipistrellus hesperus* are listed as state monitored species and *Myotis keenii* and *Coryhorhirus townsendii* are listed as state candidates (WDFW, 2003). *Myotis californicus, Lasiurus cinereus,* and *Myotis yumanensis* have no state listing but are classified as protected wildlife (WDFW, 2003). Without further investigation into the cause of these declines, some bat species may go extinct (Erickson, 1998).

Within Washington, 16 bat species are thought to be present: *Myotis* species (*Myotis californicus, Myotis ciliolabrum, Myotis evotis, Myotis keenii, Myotis lucifugus, Myotis thysanodes, Myotis volans, Myotis yumanensis*), pallid bats (*Antrozous pallidus*), big brown bats (*Eptesicus fuscus*), spotted bats (*Euderma maculatum*), silver-haired bats (*Lasionycteris noctivagans*), hoary bats *(Lasiurus cinereus),* western red bats (*Lasiurus blossevillii*), Townsend's big-eared bats (*Plecotus townsendii*) and western pipistrelle (*Pipistrellus hesperus*). Of these, pallid bats, western red bats, spotted bats, western small-footed bats, and western pipistrelle are not likely to be in the area of the Olympic National Park (Erickson et al., 1999).

The Olympic National Park has been surveyed previously by Janet Erickson, Kurt Jenkins, and Justin Yeager in 1998 and 1999 (Erickson et al., 1998 and 1999). The abandoned mines within the Olympic National Park were surveyed in 1998 by John Fleckenstein (Fleckenstein, 1998).

Forest dwelling bats of the Pacific Northwest have been shown to prefer old-growth forests over young and mature forests (Thomas and West, 1991). For roosting they prefer forests and for foraging they prefer clearings and bodies of water (Hogberg et al. 2002). Bats travel from forests to bodies of water by habitual flyways in order to get water to drink and to forage on insects attracted to the water. In fact feeding rates over water are 10 times greater than those near the forest roosting areas (Thomas and West, 1991).

Within the forest, local bat species prefer to roost in trees. They roost in cracks, peeling bark, foliage, abandoned woodpecker hollows and cavities in snags (Erickson, 1998 and Kalcounis et al. 1999).

The Olympic peninsula has a variety of variables of interest related to the study of bats. Lands on the east side of the mountains in the rain shadow are far drier than those on the unprotected west side. Elevations on the peninsula range from sea level to above 1,830 meters.

Different forest types, such as Sitka spruce and Douglas-fir, are thought to show differences in species composition (Erickson et al., 1999). Sitka spruce and Douglas-fir were present on the low/wet study sites and Douglas-fir was dominant on the low/dry study sites.

The climate of the Pacific Northwest ranges from cool and wet in certain areas to warm and dry in others. The bats of the area are thought to prefer areas that have high insect availability. Bats are small and have high surface area to volume ratios and so they must either forage continuously to maintain homeothermy or enter a state of torpor to conserve energy (Lausen, 2002). Flight is especially draining on energy reserves and precipitation levels may also have an effect on bat activity levels in an area due to these high costs (Lausen, 2002).

The Olympic peninsula's high habitat diversity has the potential to show many variations in bat community distribution and demographics, as the many species of bats in Washington state can take advantage of its multitude of habitats. The biology of tree dwelling and homeothermy requirements of bats and the great range of precipitation available on the Olympic peninsula make the peninsula an ideal place to investigate bats and the affects of precipitation levels on bat communities.

Objectives

The Olympic National Park spans a wide range of elevation and precipitation levels which affect bat activity and could affect the sex ratio. It contains both Sitka Spruce and Douglas-fir stands which have been shown to affect the composition of bat communities (Erickson et al., 1999). The main focus of this study was to determine how the various precipitation levels in the park affect bat communities. This survey sampled wet and dry environments at low elevations.

In the study, the goals were to:

1) Use capture data to determine if sex ratios are skewed towards males (and non-reproductive females) on the wet side of the peninsula and if they are skewed towards reproductive females on the dry side of the peninsula.
2) Collect data on species compositions in dry and wet environments, using Tuttle traps, and determine if species are present in both environments.

Methods

<u>Field Methods</u>

For this analysis two study areas were analyzed: low/wet and low/dry. For the purpose of this study, low was defined as 500 meters above sea level and below. Within each of the study areas 4 sites were chosen, and the individual sampling sites were at least 0.8 km apart to maintain site independence (Stephen West, personal communication). The distance chosen was estimated to be the minimum separation needed to avoid capturing/detecting the same bats at different sample sites.

Sites were chosen as we came upon suitable areas where we determined that there might be high bat activity. Tuttle Traps were set in areas surrounded by brush or tree limbs so that bats would be funneled through them. These were areas where bats would be likely to be commuting between roost and forage sites. In these flyways bats should not actively echolocate and be easiest to catch (Holroyd, 1994). Every attempt was made to set traps in areas where they would not block or impede human park visitors .

The four low/dry sites were located in Miller Peninsula State Park (Appendix B). The first site (Miller H1) was located along a forest trail and was at approximately 104 m in elevation; the GIS coordinates were X503245 and Y5325912. The second site (Miller H2) was located in a dry wetland and was at approximately 309 m in elevation; the GIS coordinates were X4503301 Y5326281. The third site (Miller H3) was located along a forest trail and was at approximately 262 m in elevation; the GIS coordinates were X499779 and Y5324584. The fourth site (Miller H4) was along a different forest trail and was at 246 m in elevation; the GIS coordinates were X505206 and Y5324556 (see Appendix C for map with sites labeled).

The four low/wet sites were located within Olympic National Park near Quinault Lake (Appendix A). The first site (Quinault H1) was located within an area dominated by PISI and ALRU and was at approximately 442 m in elevation; the GIS coordinates X442531 and Y 5264839. The second site (Quinault H2) was located in a forest wetland and was at approximately 368 m in elevation; the GIS coordinates were X444601 and Y5265204. The third site (Quinault H3) was located in a wetland meadow and was at approximately 368 meters; the GIS coordinates were X448161 and Y5264871. The fourth site (Quinault H4) was located near Kestner Homestead and was at approximately 287 m in elevation; the GIS coordinates were X438237 and Y5262209 (see Appendix C for map with sites labeled).

No bat trapping method is perfect in getting a full count of bats; big brown and hoary bats, for example, are high fliers and forage at up to 50 m above the ground, well out of the range of Tuttle traps (Christy and West, 1993). To capture the largest possible variety of bat species, placement of nets and traps was vital. If the trap does not cover an entire gap bats simply fly over or around it and are not captured.

Traps were set either during the day as we came upon the sites or mid-afternoon/late evening on nights when we were returning to sites for additional trap nights. Traps were then checked early in the morning by at least two team members so that one person could handle and take measurements of the bats while the other person could record data. Forearm length, ear length and foot length were measured using 12-inch plastic rulers. Sex was determined by looking for male genitalia. If a bat was determined to be female, pregnancy or recent reproduction was determined by palpating the abdomen or blowing on the fur to check for swelled nipples. Adulthood was determined by shining a flashlight through the wing joints to check for ossification. If the bat was determined to be a species that was previously underrepresented, a hair sample was taken for DNA testing using a pair of tweezers; the hair was then deposited into a test tube containing ethanol. Once a bat's measurements were taken and its sex was determined each bat was weighed by placing the bat into a plastic bag and hanging the bag from a 100 gram scale. Finally, the bat was placed into a pocket or other warm area so that it could warm up before flying away. Temperature was taken during each visit to each site using a digital indoor/outdoor thermometer. Fishing line was kept handy to replace broken line. For some locations flagging tape was tied to trees to warn hikers and to assist in relocating hard to find traps.

Analytical Methods

Sites Miller H2 and Quinault H2 were not used in data analysis since there were no captures at either site.

To determine if high and or low precipitation skewed the sex ratios, paired t-tests were performed. For each site, each night's number of reproductive females was added together to get a site total; the same was done for non-reproductive females/males. A one-tailed paired t-test, using an alpha of 0.05, was then performed using the site totals for each site within each area: low/dry and low/wet.

The null hypothesis used for the low/dry area was that the number of males and non-reproductive females combined is greater than or equal to the number of reproductive females, and the null hypothesis for the low/wet area was that the number of reproductive females is greater than or equal to the number of males and non-reproductive females combined. A two-tailed paired t-test, using an alpha of 0.05, was then performed to determine if equality could be ruled out.

Results

The null hypothesis used for the low/dry area that the number of males and non-reproductive females combined is greater than or equal to the number of reproductive females was not rejected.

The null hypothesis for the low/wet site that the number of reproductive females is greater than or equal to the number of males and non-reproductive females combined was not rejected.

Chart 1: Paired t-test results.

	Mean	***SD***	***n***	***t-value***	***df***	***P(one- tailed)***	***P (two-tailed)***
Miller	7	57	3	0.2127	2	P>.25	P>.5
Quinault	3.67	102.38	3	0.0358	2	P>.25	P>.5

The numbers used to perform the t-tests can be found in Appendix D.

Myotis californicus, Myotis evotis/Myotis keenii, Myotis lucifugus, Myotis volans, Eptesicus fuscus, Lasionycteris noctivagans and possibly *Myotis thysanodes* were captured at the low/dry Miller sites. *Myotis californicus, Myotis ciliolabrum, Myotis evotis/Myotis keenii, Myotis lucifugus, Myotis yumanensis* and *Plecotus townsendii* were positively identified at trap locations in the low/wet study area near Quinault Lake. For specific numbers of each species caught see Appendix E.

Discussion

Due to the low number of sites used and the inability to have further repetition the results shown above are not necessarily correct. The paired t-tests show that the number of males and non-reproductive females is equal to or greater than the number of reproductive females on the dry side of the peninsula and that the number of reproductive females is equal to or greater than the number of males and non-reproductive females. This is opposite to the expected results. The two-tailed paired t-test failed to rule out equality. This could mean that there is no skew to the sex ratios dependent on precipitation levels.

Females seek the best areas in terms of temperatures and insect abundance while leaving the less demanding males poorer quality habitat (Ford, 2002). However, sex ratios have been also been shown to be skewed by elevation and other geographic reasons (Ford, 2002). Due to the strange weather in Washington state during the summer of 2003 it may not be possible to distinguish sex ratios for an average year in the wet and dry areas of the peninsula. In 2003 Washington experienced its driest summer since 1900; rain amounts were from 70 to 85 percent below normal (The Seattle Press, 2003). Although, precipitation is a likely determinant of sex distribution and lower precipitation level may help in thermoregulatory efficiency of foraging reproductive females (Cryan, 2000), the results of the study did not indicate a sex ratio skew.

Since there was great variation between sampling nights, the captures were pooled. While this reduced variance, the sample size was still too small to reach a conclusive result. Another study should be conducted using more sites on more nights.

Eptesicus fuscus, Lasionycteris noctivagans, Myotis volans, and Myotis thysanodes were only found on the dry sites and *Plecotus townsendii* was only found at one of the wet sites. Since the capture data was only collected using Tuttle traps, there may also be bias in species presence. The sites within each area were chosen so that they were as similar in elevation and habitat as possible so that there were no confounding sources of error in species presence related to precipitation.

Only a single bat was identified as *Myotis thysanodes* on the dry side of the peninsula. The bat fit the description of *Myotis thysanodes* given in Bats of British Columbia which we were using as our guide. We were not certain of this identification, however. Further trapping should be conducted to determine if the classification was correct.

Plecotus townsendii inhabits several habitats in British Columbia, an environment similar to Washington state. It has been shown to roost in buildings near humid coastal areas, caves and old mines (Nagorsen & Brigham, 1993). These preferences may indicate why it was found on only the wet side of the peninsula near a homestead on one site. The availability of suitable roosting areas may be what allows *Plecotus townsendii* to inhabit this wet area.

Eptesicus fuscus, *Myotis volans* and *Lasionycteris noctivagans* appear to be generalists, using several different environments (Nagorsen & Brigham, 1993). Their detectable presence on only the dry side of the peninsula may be due to the limited amount of sampling. Further study will be necessary to determine whether they are in fact absent on the wet side of the peninsula.

It appears that the gradient of precipitation on the Olympic peninsula has little effect on bats. Sex ratios do not appear to be skewed towards reproductive females on the more energy efficient dry part of the peninsula. *Myotis californicus* was an abundant species at both ends of the precipitation gradient. More species were present on the dry side of the park than the wet side.

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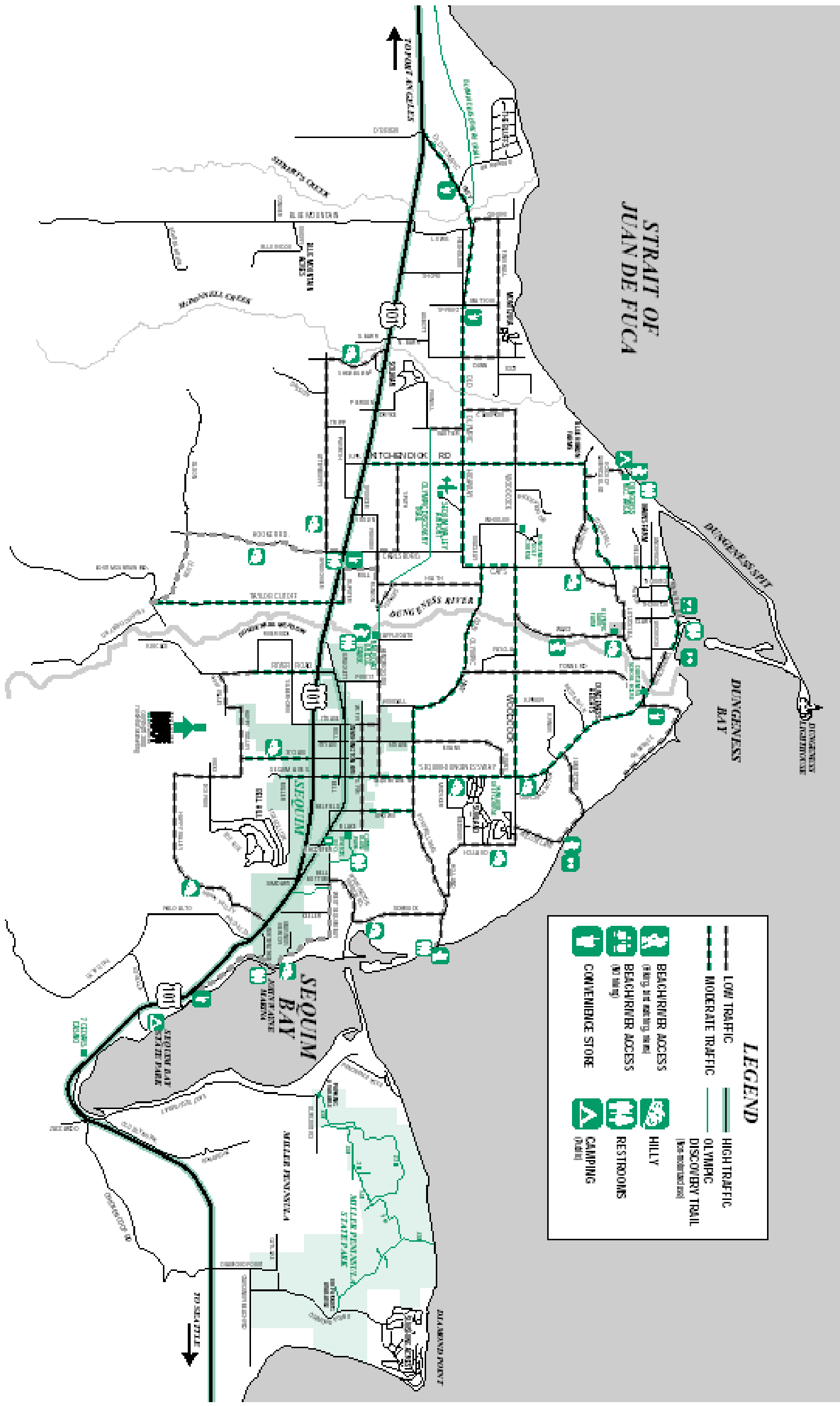
Appendix A

Graphic: Olympic National Park with Quinault low/wet sampling area circled.

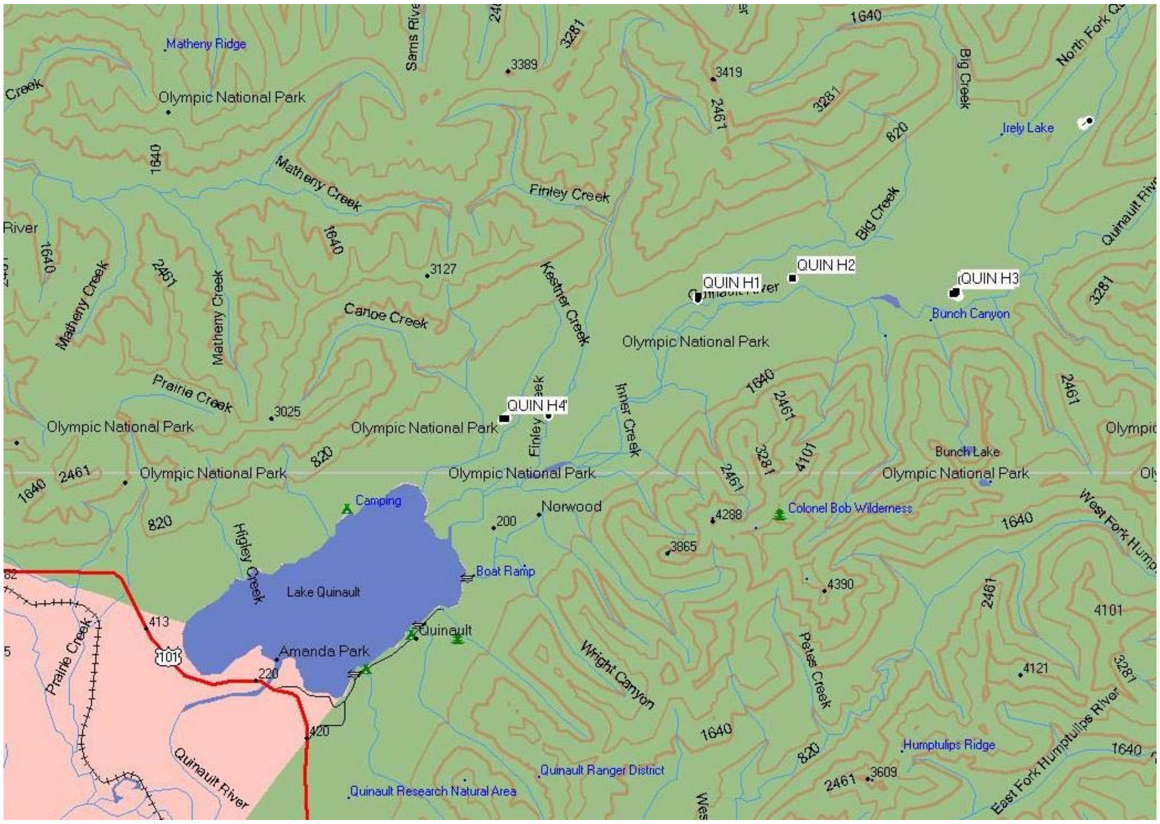
Appendix B

Graphic: Miller Peninsula State Park map showing location relative to Sequim.



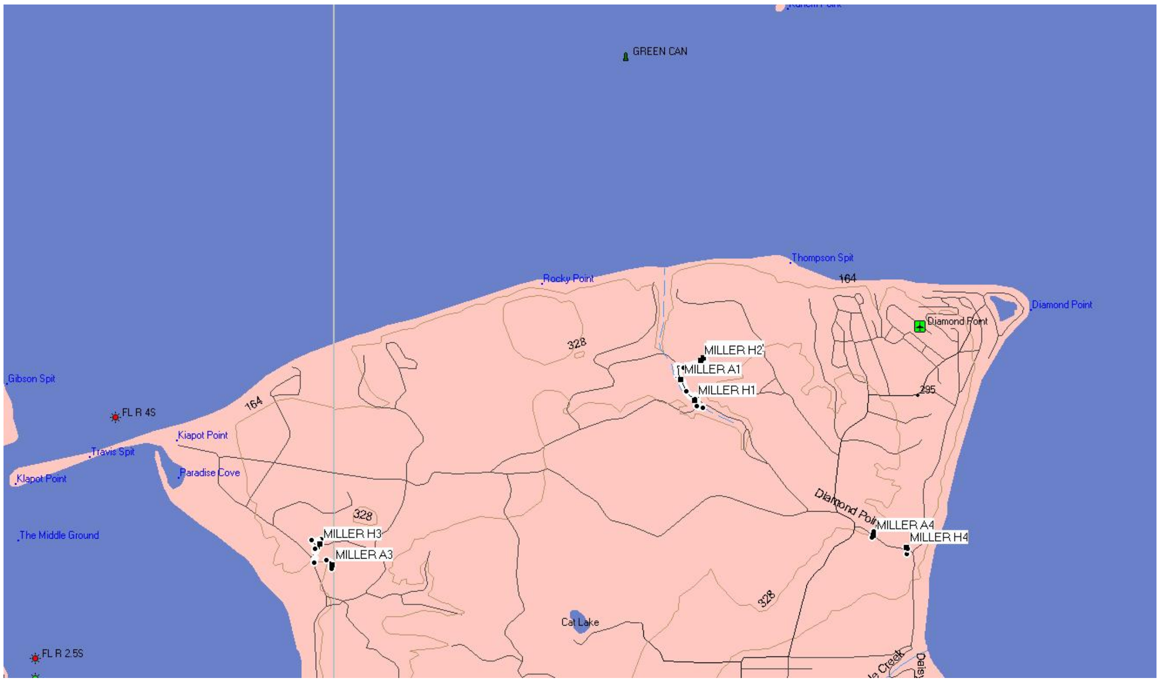
Appendix C1

Graphic: Quinault H1, H2, H3, H4 from GPS unit



Appendix C2

Graphic: Miller H1, H2, H3, H4 from GPS unit



Appendix D. Captures according to site, date, and sex.

	Dates	Males	Non-Rep Females	Rep Females	Unknown
MH3	06/17-06/18	3	1	1	0
	06/18-06/19	8	0	4	0
	07/14-07/15	0	0	0	0
	07/15-07/16	1	0	0	0
MH1	06/17-06/18	0	0	0	0
	07/14-07-15	4	0	0	0
	07/15-07/16	11	3	4	0
MH4	06/18-06/19	1	2	4	0
	06/19-06/20	2	1	2	0
	07/14-07-15	1	0	1	0
	07/15-07/16	0	0	1	0
QH1	06/24-06/25	2	1	0	0
	06/25-06/26	0	0	0	0
	07/07-07/08	0	0	0	0
	07/08-07/09	0	0	0	0
QH3	06/24-06/25	0	0	0	0
	06/25-06/26	4	1	2	0
	07/07-07/08	3	1	2	0
	07/08-07/09	0	0	0	0
QH4	06/25-06/26	2	2	14	0
	06/26-06/27	16	3	17	2
	07/07-07/08	0	0	7	0
	07/08-07/09	0	0	4	0

Gender of Bats

Appendix E. Species presence by site and date.

Species of Bats

	Dates	MYCA	MYEV/KE	MYLU	MYTH	MYVO	MYYU	LANO	EPFU	PLTO
MH3	06/17-06/18	4	0	0	0	1	0	0	0	0
	06/18-06/19	7	3	1	0	1	0	0	0	0
	07/14-07/15	0	0	0	0	0	0	0	0	0
	07/15-07/16	1	0	0	0	0	0	0	0	0
MH1	06/17-06/18	0	0	0	0	0	0	0	0	0
	07/14-07-15	4	0	0	0	0	0	0	0	0
	07/15-07/16	14	1	1	0	0	0	1	1	0
MH4	06/18-06/19	6	0	0	1	0	0	0	0	0
	06/19-06/20	5	0	0	0	0	0	0	0	0
	07/14-07-15	2	0	0	0	0	0	0	0	0
	07/15-07/16	1	0	0	0	0	0	0	0	0
QH1	06/24-06/25	2	0	0	0	0	1	0	0	0
	06/25-06/26	0	0	0	0	0	0	0	0	0
	07/07-07/08	0	0	0	0	0	0	0	0	0
	07/08-07/09	0	0	0	0	0	0	0	0	0
QH3	06/24-06/25	0	0	0	0	0	0	0	0	0
	06/25-06/26	4	0	0	0	0	3	0	0	0
	07/07-07/08	5	0	0	0	0	1	0	0	0
	07/08-07/09	0	0	0	0	0	0	0	0	0
QH4	06/25-06/26	5	0	5	0	0	0	0	0	8
	06/26-06/27	5	1	26	0	0	0	0	0	6
	07/07-07/08	0	0	0	0	0	0	0	0	7
	07/08-07/09	0	0	0	0	0	0	0	0	4

Appendix 4. Patrick Adam. Relative species composition of bats in Sitka spruce and Western hemlock forests on the Olympic Peninsula. Bachelor of Science Thesis.

Relative Species Composition of Bats in Sitka spruce
and
Western hemlock forests on the Olympic Peninsula

by

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A senior thesis submitted in partial fulfillment
Of the requirements for the degree of

Bachelor of Science

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Abstract

Species composition of bats may differ substantially between comparable age class stands of Sitka spruce and western hemlock forests within Olympic National Park. This study investigates previous indications of this phenomenon for a more thorough understanding of habitat requirements and niche partitioning for vespertilionid bat species. Our goals are to compare relative activity and species composition between Sitka spruce and western hemlock forests using both direct capture and echolocation detection techniques. Positive species identification and acquisition of basic morphological and biological characteristics was attained through use of both harp traps and mist nets. Relative activity levels between sites were made with the use of automated bat echolocation equipment. ArcView GIS was used to analyze land cover data for plots chosen as trapping sites to determine percent coverage of a given tree species. Four species of bat, *M. californicus, M. yumanensis, M. lucifigus,* and *M. evotis* were as likely to be found in Sitka spruce forests ($\bar{x} = 6.00, \bar{x} = 1.67, \bar{x} = 9.50, \bar{x} = 0.17$) as in western hemlock forests ($\bar{x} = 4.75, \bar{x} = 0.25, \bar{x} = 1.25, \bar{x} = 0.75$). Although these values are statistically insignificant with *P* values of ($P = 0.683, P = 0.308, P = 0.287, P = 0.214$), the analysis does not take into consideration the interactive effects of elevation which may have an effect on the final analysis. The results imply no difference in bat species composition between forest types which may in part be due to a lack of sharp segregation between Sitka spruce and western hemlock trees.

Introduction

Many studies of the roosting and foraging behavior of bats in both managed (Campbell, Hallett, and O'Connell, 1996; Thomas and West, 1991) and unmanaged forest ecosystems (Wunder and Carey, 1996; Lunde and Harestad, 1986) in the Pacific Northwest, from Oregon north to British Columbia, have been accomplished within the past 20 years. While the results of this research have illustrated the important relationship between old-growth forests of differing temperature and moisture regimes (Erickson and West, 2002; Grindal *et al*., 1992), and the preference most bat species have for selecting older trees for roost sites (Barclay and Brigham, 2001; Brigham *et al*., 1997), little research has been undertaken that contrasts the relative abundance and species composition of bats between stands of differing forest series and cover type (but see Christy and West, 1993; Kalcounis *et al*., 1999; Perkins and Cross, 1988).

Of the 16 species of bats that are present in Washington state, the Yuma myotis (*Myotis yumanensis*), California myotis (*M. californica*), Little brown myotis (*M. lucifugus*), Long-legged myotis (*M. volans*), and Northern long-eared myotis (*M. evotis*) are most abundant in Olympic National Park (Jenkins, Erickson, and Yeager, 1999), while additional species such as the Hoary bat (*Lasiurus cinereus*), Silver-haired bat (*Lasionycteris noctivagans*), Townsend's big-eared bat (*Plecotus corynorhinus townsendii*) (Fleckstein, 1998), and Big brown bat (*Eptesicus fuscus*) are known to inhabit (Jenkins *et al*., 1999) the Olympic peninsula. A complete and accurate catalogue of species present on the Olympic peninsula is necessary for two reasons: to provide information for forest and wildlife biologists to make appropriate ecosystem management decisions; and to enable biologists at Olympic National Park to record the change in bat activity and species composition over time which may be an indicator to the overall health of the park ecosystem.

Prior studies of bat species composition and distribution within the Olympic Peninsula, supporting Olympic National Park's Long-term Ecological Monitoring program (Erickson *et al*., 1998; Jenkins *et al*., 1999), have uncovered relationships between bats and their habitat preferences that were previously overlooked. Preliminary research indicates a distinct change in relative abundance and composition of bat species between late seral western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*) forests within the park.

As part of a continuing species inventory study for the park, our purpose was to further delineate these differences and determine not only relative abundance and composition between genus, but also within the *Myotis* genus, as we expected the proportion of *Myotis. spp.* to differ between western hemlock and Sitka spruce forest types.

Direct capture techniques were used to generate an index of relative abundance and species composition between the two forest types, assessing spatial variability within each forest type and between stands. ArcView GIS (ESRI, Redlands, CA) was utilized to determine relative percent tree species composition surrounding each trap site.

The primary goal of this project was to verify and catalogue the presence of vespertilionid bats within Olympic National Park as a whole, irrespective of relative activity or species composition for a given area. The secondary goal was to examine the relative activity and species composition within low (<150 m) to mid (<900 m) elevation stands of late seral western hemlock and Sitka spruce forests of similar age class or average diameter at breast height (dbh). An average of 20% of the forest surrounding each of the traps sites was comprised of trees with 81 cm (32”) DBH or greater, with a maximum of 30% at the Hoh river site and a low of 9% at the Lake Ozette site.

Research has begun to identify a number of critical requirements of forest dwelling bats (Furlonger, Dewar, and Fenton, 1987; Jaberg and Guisan, 2001; Leonard and Fenton, 1983; van Zyll de Jong, 1994; Vonhof and Barclay, 1996), such as deeply fissured bark or cavity filled snags (representing a structural roost component that is also important for maternity colonies), which, combined with this and future efforts may be used to correlate bat species with forest series. This in turn may be added to a larger model that predicts the presence or absence of a species given the forest type and age class.

Of four species of bats, *M. californicus*, *M. yumanensis*, *M. lucifigus,* and *M. evotis*, none were more likely to be trapped in Sitka spruce forests than in western hemlock forests. However, three of the western hemlock sites were located at mid elevation (600m – 900m) which was not taken into account in the simple one way ANOVA. Elevation and proportional dbh effects should to be incorporated into a multiple linear regression model along with forest type to understand their interactions which may result in a different conclusion.

Methods

Study Area

Study sites include the coastal western hemlock forests located near the Ozette ranger station, and mid elevation western hemlock forests at the Sol Duc river and Three Lakes sites above the North Fork Quinault River. Low elevation riparian Sitka spruce forests found along the Quinault, Queets, and Hoh rivers represent the inland Sitka spruce forests. All of these study sites are characterized by an average annual precipitation of 2540-3048 mm, and range from sea level along the coastal western hemlock stands to 500 meters along the upper Hoh River (at the visitor's center) to a maximum of 900 meters at Three Lakes. The unusual inland extension of Sitka spruce is made possible by summer fogs and the close proximity to the Pacific Ocean (Franklin and Dyrness, 1988).

Site Selection

Sample sites within each of the two treatments (forest series; either Sitka spruce or western hemlock) were defined by a minimum 400 meter radius, ensuring a minimum of 500 meters separation between trapping and echolocation detection stations. Only one sample site for each survey method was located within a stand. A potential bat species composition gradient may exist between the Sitka spruce stands along the Quinault, Queets, and Hoh river drainages. However, due to limitations of equipment, time, and field personnel, a sampling design that accounts for within stand variation could not be accommodated. Sample sites within each stand were located equidistant from potential foraging sites as terrain and access allowed. An additional criterion used for selection of individual sites was tree diameter. I used stands that averaged greater than 81cm DBH in both treatment types to ensure the greatest number of favorable roosting sites such as deeply fissured bark in the western hemlock stands and large, cavity filled snags in both forest series. Potential roosting and foraging sites were surveyed in both forest types to discern if species composition changed between them.

Differentiation between Sitka spruce forests and western hemlock forests was based on a minimum 7% Sitka spruce composition out of all species present that were categorized as meadow, shrub, Douglas-fir, western hemlock, mix conifer, western red cedar/western hemlock mix, western red cedar, Alaska yellow cedar, hardwood mix, bigleaf maple, or red alder. Sites meeting this criterion still contain up to 55% western hemlock based on vegetation characteristics defined by digital Landsat Thematic Mapper (TM) satellite imagery and field collected data.

Field Methods

Direct capture methods were used to positively identify bat species while ultrasonic detection methods were used to identify general presence and relative activity between sites.

Harp Traps

Harp traps were placed in potential commuting corridors such as forest trails and narrow roads within the forest that lead to clearings and riparian areas. Harp traps are particularly useful with our limited personnel, as a number of these traps were left unattended overnight, thereby increasing our ability to sample additional areas in a given site that is otherwise not possible with mist nets that must be constantly monitored by two people and subsequently dismantled after dusk and dawn sampling events. Mist nets were used in forest clearings, along forest clearing edges, near small bodies of water, and across small streams to intercept foraging and drinking bats.

Harp traps are relatively diminutive in size compared to the potential area of a flyway they are intended to sample from and as such are limited in their application. Care must be taken to install these traps in corridors surrounded by dense foliage effectively leaving no alternative route for the bats to pass through. Additionally, due to the short stature of these traps (<3 m), high flying species such as the Hoary and Big brown bats are typically excluded from this sampling technique, effectively rendering these species as invisible.

Mist Nets

Mist nets span a much larger area and are better suited for more open environments such as wide road cuts through forest interiors, clearings, over streams and near ponds. These nets are also prone to excluding the higher flying species unless placed to span a pond, in which case the bats may be intercepted when skimming the surface for a drink. One additional limitation of mist nets is the ability of bats to maneuver over the net when placed in foraging areas due to the slower flight and increased sensitivity bats have to objects when echolocating for insects. The placement height for effective capture depends on the landscape structure in which it is being installed.

Ultrasonic Call Detection

To overcome these biases and provide improved data on bat activity, ultrasonic detection equipment was used as well. Three types of data may be collected with ultrasonic bat detectors including presence or absence of bat activity, species identification, (either individual or species groups depending on similarity of call structure), and feeding versus commuting calls which is an indicator of habitat use and preference. Advantages include continuous sampling throughout the night, monitoring of several sites simultaneously, and the ability to sample bat activity throughout the vertical canopy strata.

While simultaneous sampling across all sample sites is preferred to reduce intrastand and interstand variability, the lack of equipment, vehicles, and personnel make this design scheme unfeasible, the outcome of which will be high spatial and temporal variance which may be mitigated in part by randomized block or paired sample designs (Hayes, 1997). A number of other confounding factors must be taken into account when sampling with bat detectors (Thomas and West, 1989). For example, variation in sample period as the season progresses, or failures in equipment that reduce sample time must be standardized before bat activity can be compared between nights. Phenological variation throughout the season will affect activity levels as females do not typically return to day roosts during breaks in evening feeding while gestating during May and June. When females begin lactation, however, they will return to the maternal day roost colonies to feed their young in July, shifting both the spatial and temporal arrangements of their activity. Weaning in August produces an increase in population and a corresponding increase in activity that may be interpreted as an increase in preference for a specific roosting or foraging area. For these reasons, it is preferable to complete sampling across all treatments before conclusion of a given period in the phenological development of bats. Due to the interdependence of this study on equipment, vehicles and personnel being used in complimentary studies, data collection spanned two phenological periods (gestation and lactation) due to weather and scheduling.

Abiotic factors conspire as well to confound the interpretation of bat call detections. High frequency components of a bat call are subject to atmospheric attenuation at a much quicker rate than the low frequency component. This results in some loss of resolution, but fortunately many calls are characterized by a rapid decay of the high frequency component, while the lower frequencies decay at a lower rate. This results in retention of a majority of the call signature that may still be used to distinguish a species or species group.

Design Scheme

The aforementioned constraints on equipment and personnel have limited our ability to perform as robust a survey as we would like to maintain higher levels of statistical power. One sample site for each survey method (echolocation detection and direct capture) was located in each of 10 stands (six replicates of Sitka spruce and four replicates of western hemlock) in an attempt to sample each site for a total of 4 nights.

Harp traps are the most efficient direct capture method in terms of person effort, but maybe less so in terms of areal capture efficiency. Four of the 10 sample sites (two of each treatment type) were surveyed in two night increments, requiring one additional visit to each site to complete a total of 64 trap and detector nights. This rotation scheme was intended to minimize temporal variation across sites. We were successful in sampling for four nights in the Quinault and Hoh river drainages and in the Queets drainage at site H2. The Ozette H1 site was also successfully sampled for four nights. We managed only two nights at Three Lakes, three nights in the Sol Duc drainage, and two nights of trapping at Ozette site Rd1 for a total of 50 trap nights.

Collected bats were identified to species, sexed, and age determined to juvenile or adult. Reproductive status of females was noted along with measurements of weight, foot length, ear length, tragus length, and forearm length.

Bat detection units were placed ~1 m above ground surface at a 30˚ incline to prevent truncation of the microphone receiving cone and were directed to sample from open understory, avoiding clutter that will impede incoming bat calls resulting in negative bias. Calls were recorded from sundown to sunrise. Unfortunately, various components of the echolocation detection equipment began to fail within the first week of use. Because this study took place concurrently with other aspects of the larger study, we obtained only 10 nights of acoustic data, some of which contained no useful information due to noise or intermittent failure. Consequently, no useful comparisons could be made among sites due to inadequate sample size.

Analytical Methods

Analysis of direct capture counts was made on the total sum of all bats captured per treatment area and subdivided into the total number of each bat species captured per treatment area. Relative species composition was compared between treatment sites through a one way ANOVA using SPSS software (Chicago, IL).

The proportion of Sitka spruce and western hemlock in the sample sites was determined using ArcView GIS. Using the Vegetation Species in Olympic National Park coverage file (NPS, 2001), pixels for each of 26 vegetation and non-vegetation (rock, water) types were summed for sample sites within an area bounded by a 400 meter radius. This area approximates the distance between roost and foraging sites that Northwest vespertilionids typically fly. Sitka spruce and western hemlock were then calculated as a fraction of the total for each site.

Results

The proportion of Sitka spruce found in those sites designated at 'Sitka spruce' was 7.6% in the Quinault river drainage, 11.7% in the Queets river drainage, and 11.4% in the Hoh river drainage. Both of the values for Quinault and Queets are comprised of all sites within their respective drainages. Western hemlock accounted for 24.8%, 54.8% and 43.8% of these sites, respectively. Three Lakes, Ozette, and Sol Duc sites designated as 'western hemlock' forest types were comprised of 50.8%, 37.3% and 63.4% western hemlock, respectively. In both forest types, the majority of remaining species were comprised of red alder (*Alnus rubra*) and Douglas-fir (*Pseudotsuga menziesii*).

In five cases, the mean number of bats for each species was not significantly different (MYCA, $P = 0.683$; MYYU, $P = 0.308$; MYLU, $P = 0.287$; MYEV, $P = 0.214$; MYLU/YU, $P = 0.713$) between forest types resulting in a failure to reject the null hypothesis that bats would be as likely to inhabit Sitka spruce forests as they would western hemlock forests. *Plecotus townsendii* was not included in the statistical analysis for two reasons; (1) they were present only in one study site in one forest type and (2), were likely to have been present in such high numbers due to a maternity colony located in the old buildings of the Kestner Homestead. Table 1 summarizes the descriptive statistics of the study, while Table 2 summarizes the inferential statistics. Complete output of the statistical analysis is located in Appendix A.

Discussion

Strong correlation between bat species composition and distinct, but nearby forest types subject to similar environmental affects, may reveal another component to the complex model that describes bat roosting and feeding habitat requirements. Not only has seral stage of managed and unmanaged forests been shown to affect bat species composition in a given ecotone, but so too may forest series or cover type even if average dbh and sub-canopy forest structure are homogenous between the forest types. The results of this study imply that there is no difference in bat species composition between forest types, although both *M. lucifigus* and *M. evotis* are much closer to showing a differentiation between forest types. Without taking into consideration the interactive effects of elevation with forest type and bat species composition, the above results are not entirely conclusive. The proportional composition of each replicate site with respect to DBH should also be included in the study, since a forest with a higher percentage of tree stems >81 cm DBH will likely support more bats. Those that are particularly selective of roosting in the crevices of bark will find more places to roost, unless the majority of the trees >81 cm DBH are Sitka spruce, in which case bark roosting is less desirable due to lack of large bark flakes. A multiple linear regression model would be necessary to include these two additional variables because the sample sizes are different for each of the forest types. Had the sample sizes been equal in number, a multiway factorial analysis would have then been suitable.

Another difficulty in showing any preference of bats for roosting in Sitka spruce trees is the large dominance of western hemlock in the river drainages, for although a site may contain 11% Sitka spruce such as found in the Queets drainage, it also contains as much or more western hemlock (54.8%) as sites that contain no Sitka spruce. Because of the small proportion of Sitka spruce and its relatively smooth bark compared to western hemlock, it likely plays a minor role as a selection criterion by vespertilionids in the Northwest. Sitka spruce trees are also dispersed quite uniformly among the western hemlock trees in the lowest part of the drainage. However, other morphological

Table 1. Total count of all species trapped in both treatment types.

Forest Site		Number of Species						Total
		MYCA	MYYU	MYLU	MYEV	MYLU/YU	PLTO	
PISI	Quin H1	2	1	0	0	0	0	3
	Quin H3	10	4	0	0	0	0	14
	Quin H4	10	0	31	1	0	25	67
	Queets H1	1	0	1	0	0	0	2
	Queets H2	4	0	1	0	0	0	5
	Hoh H1	9	2	24	0	3	0	38
TSHE	Sol Duc H1-H3	5	0	3	2	0	0	10
	Sol Duc H4	1	0	0	0	0	0	1
	Ozette H1	12	1	1	0	1	0	15
	Th. Lks. H2B	1	0	1	1	0	0	3
	Total	55	8	62	4	4	25	158

Table 2. Mean number of bats captured within each treatment type.

Forest Series	Species (mean ± s.d.)				
	MYCA	MYYU	MYLU	MYEV	MYLU/YU
PISI	6.00 (4.15)	1.17 (1.60)	9.50 (14.1)	0.17 (0.41)	0.50 (1.22)
TSHE	4.75 (5.18)	0.25 (0.50)	1.25 (1.26)	0.75 (0.96)	0.25 (0.50)

characteristics of Sitka spruce such as the open, drooping branches may provide good roosting for bats that prefer branches such as the Hoary bat (*Lasiurus cinereus*).

After several unsuccessful attempts at using the mist net for capture, we decided to use the harp traps exclusively. We used the mist net at high and low elevation sites that either spanned a creek or was erected at the side of a pond. We caught no bats but watched several dodge to the side or over top the net. We assumed they were in feeding mode rather than just flying over water for a drink, and as a result were 'illuminating' the nets fine surface with the higher frequency feeding buzz and its associated finer spatial resolution.

The failure of the echolocation detection equipment did not substantially affect the results of this study, other than deprive us of an indication of activity levels between forest types and sites. Because the majority of species caught in these two forest types were *Myotis spp.*, aside from the local concentration of *P. townsendii*, the reliance upon echolocation records as a means of discrimination between species would not have resulted in data we would have been confident with. One of the better uses that the loss of this equipment prevented us from pursuing was the ability to determine if the area in which we set up harp traps had any bat activity whatsoever. Two additional sites we had selected for western hemlock replicates on DNR land yielded not one capture. One of these forests was an old-growth island remnant, surrounded by mid-seral regeneration, that had never been cut. The forest was a mix of western hemlock and western red cedar that contained dozens of ancient candelabra snags that towered over the complex structure of the understory. There were plenty of flyways and we set our trap in a marshy clearing that one would expect an abundance of insects to attract bats from any of several fine roosts. Without the aid of bat detectors to inform us of any activity we could not be certain we were trapping in the right spot.

Improvements to the design and execution of this study have two main components. One is the equipment preparation prior to the study and the other is performing a reconnaissance mission for suitable sites prior to the formal trapping session.

The main equipment weakness of this project was the Anabat detection system. The technology is antiquated, and while not a problem in itself, does lead to equipment failure. The ultrasonic frequency detector is a durable unit and gave us very little trouble in the field and draws a small amount of current compared to the rest of the system. The weakest link in the chain is the delay switch, which is mostly solid-state but the few moving parts that it does incorporate such as the dials have failed in many of the detection kits. It also relies on two separate battery systems, both internal and both hard wired that makes them user unfriendly. The delay switch may also be powered by an external gel cell but it's not clear exactly which part of the timer its powering, as we often had a fully charged gel cell but the timer still failed. The tape recorder interface is yet another point of failure. Aside from contributing to even more signal noise, the tape recorders speed must be taken into consideration upon analysis of the signal because of the variety of speeds with which it operates at depending upon age, temperature and condition of the battery. For future studies requiring the use of echolocation equipment, I would suggest the new system Titley Electronics (NSW, Australia) has developed that eliminates the obsolete delay switch/tape recorder set-up and separate ZCAIM conversion unit. The new zero cross analysis unit incorporates compact flash memory to record the data that it has already converted from the raw output of the detector. This one unit combines a timer, delay switch, tape recorder thereby eliminating the tangle of cables and life support systems associated with the older systems. It is a programmable unit that incorporates a GPS port so that positional data may be downloaded and incorporated directly into the call database.

The use of these superior detector units would then be used to scout potential trapping sites, probably a year prior to the formal study, to get an indication of areas that show reasonable levels of activity such that it is more probable that a researcher would capture bats at these locations. It is very difficult and time consuming to be 'experimenting' with locations when each day counts and if lost to 'no captures' is hard to make up. The coincidental scouting and hoping one has made a good decision with respect to trap placement often results in zero bats, which makes subsequent data analysis easier, but less interesting. Obviously, most studies do not have the luxury of spending a summer finding great locations for next years research, which makes it all the more important to be equipped with high quality, functional bat detection equipment to locate promising trapping sites as quickly as possible.

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