Migratory and Non-migratory Movements and Habitat Use by Female Elk in the Cascade Range of Washington

by

Barbara J. Moeller

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

Master of Environmental Study

The Evergreen State College

Completed December 2010

© 2010 by Barbara J. Moeller. All rights reserved.

This Thesis for the Master of Environmental Study Degree

by

Barbara J. Moeller

Has been approved for

The Evergreen State College

by

____

Dylan Fischer, PHD

____

Brian A. Gilbert, PHD

____

Steven G. Herman, PHD

____

Date

ABSTRACT

Migratory and Non-migratory Movements and Habitat Use by Female Elk in the Cascade Range of Washington

Barbara J. Moeller

Most research studies have evaluated non-migratory or migratory elk (*Cervus elaphus*) behavior and their use of habitat as unique separate groups. Few studies have evaluated migratory and non-migratory elk habitat use within the same elk herd. This thesis focuses on the habitat use of female elk (*Cervus elaphus*) with a specific emphasis on the similarities and differences between migratory and non-migratory groups of elk in the southwestern Cascade Range of south-central Washington during 2004 – 2008. I used relocations on 53 radio-collared female elk and >80,000 locations on 15 GPS (Global Positioning System) collared female elk. Habitat use and movement, home range, survival, and herd fidelity were studied and measured on the collared elk to assess elk habitat use across the 1,028 km^2 study area.

Differences were detected between the migratory and non-migratory groups of elk where migratory elk were found to use steeper terrain, were in habitat areas in closer proximity to cover (safety), and tended to be found in habitat areas that were greater distances from paved roads than non-migratory elk. Annual survival rates ranged between 71% and 90% over the course of the study. Home range size ranged from 5.4-102 km^2. Differences in home range size were detected between the migratory and non-migratory groups of elk for each biological year (BYR) of the study (2004-2008) and for the overall life home range. The elk in our study also demonstrated strong site fidelity (99%).

ACKNOWLEDGEMENTS

While driving my truck the other day, I was contemplating acknowledging friends, family and colleagues that have contributed to my thesis process. During the drive Janis Joplin came on the radio. Her raspy soulful voice rang out embedded within the rich accompaniment of her band. It made me think about how talented she truly was, but what also became very clear, were the players involved in contributing to her success. The possible range of family, friends, artists that inspired her, producers, and band mates that influenced her final products were probably countless. Although my research and the resulting thesis takes place in a vastly different discipline, venue and at a much smaller scale, I am as grateful as Janis could have been to the many people that have contributed to my research project and my thesis.

I am eternally grateful to the Puyallup Tribe of Indians for providing me the opportunity to work for them, conduct research, and use the data I have collected for the thesis. Within the Tribal organization, I am especially grateful for the support of the Tribal Council, the Hunting Commission, staff and the general membership. Specifically, I would like to thank Bill Sullivan, Natural Resources Director for his continual support, flexibility, and encouragement. Very special thanks to Paul Arnold for his superb GIS expertise and very considerable mapping contributions on the project. Additional thanks to tribal project participants include: Mary Basballe, Phillip Dillon, Don Coats, and Paul Herrera. Special thanks to my predecessor Mike McDonald for initiating research on the South Rainier elk herd.

The project would not have been possible without the support of the United States Fish and Wildlife Service Tribal Wildlife Grant and the Bureau of Indian Affairs Unresolved Hunting and Fishing Rights grant. Additional thanks to cooperating agencies, tribes and organizations include: Northwest Indian Fish Commission, especially Chris Madsen, Muckleshoot Indian Tribe, especially Dave Hamilton and David Vales, Squaxin Island Tribe of Indians, especially Pete Kruger, Nisqually Tribe of Indians, Georgiana Kautz and Dave Trout, Quinault Indian Tribe, especially Grover Oakerman, Washington State Department of Fish and Wildlife, especially Briggs Hall, DVM, Robin Woodin, and Richard Stone, Mount Rainier National Park, especially Jim Schaberl, Gifford Pinchot National Forest, especially Tom Kogut and Joe Kulig.

Very special thanks to my thesis committee chairman, Dylan Fischer, for his exceptional attention to detail, guidance, and effort on the manuscript. As well, special thanks to Brian Gilbert and Steve Herman for participation on my thesis committee. Also special thanks to Ted Whitesell of The Evergreen State College.

Capturing and collaring of the elk for the study would not have been possible without expert helicopter pilot Jess Hagerman. Honorable mention goes out to Jerry and Bridgette White for sharing their home, coffee, and wood spirits and allowing us to stage elk capture from their property. Additional thanks to N. Carroll, Janie Unbehagen, DVM and staff at the Animal Care Clinic, B. Anderson, J. Foster, and the residents of Packwood and Randle for their patience and support during elk projects.

I am extremely grateful to Lesley Richardson for the inspiration to enter into graduate school and sustained support on all aspects of this project, including master edits and formatting of the manuscript. Also thanks to Charmane Ashbrook, Shon Kayli, Dr. Jennifer Holt, and sister Julie Jeronimus for extended support and encouragement. Special thanks to my partner Kathryn McMahon for loving support, thoughtful sweetness, and encouragement to persevere.

This thesis is dedicated to the memory of my father Donald D. Moeller who passed on in February of 2010. Without my father's encouragement to play hockey as a girl and pursue my dreams, as non-traditional as they were, I would not be the woman I am today! Thanks Dad!

TABLE OF CONTENTS

Item
Page

HOME RANGE, SURVIVABILITY, AND HABITAT ANALYSIS OF ELK IN SOUTHWEST WASHINGTON……………………………………………….……………1

INTRODUCTION/HISTORY………………………………………........1

STUDY AREA…………………………………………………….…8

METHODS………………………………………………………..…11

Elk Captures…………………………………..………11

Radio Telemetry………………………………………………13

Home Range and Core Use Areas……………………………..13

Survival of Cow Elk……………………………………...15

Habitat Variables………………………………………….....15

Habitat Use, Seasonal Habitat Use and Time of Day……….....19

RESULTS…………………………………………….................20

Elk Captures……………………………………..….20

Home Range ……………….…………………….........20

Migration ……..……………………………………….…24

Distribution………………………………………….....24

Survival Rates……….…………………………………………28

Item
Page

Habitat Use: Activity……………………………………………....28

Aspect……………………….………………………....30

Proximity to Cover…………………..……..…..32

Proximity to Shrub/Scrub……………….…...….37

Slope………………………………..……..…..…40

Proximity to Water………………..…………….44

Proximity to Roads and Trails………………..….47

Habitat Use with Season and/or Time as Predictors……..……54

DISCUSSION…………………………………………..…………...55

Home Range…………………………..……………….…55

Migration and Distribution………………………………….57

Survival Rates…………………………………...………..57

Habitat Use: Aspect……………………………...……….58

Slope…………………………………….....…...60

Proximity to Cover………………....…………..60

Proximity to Shrub/Scrub………..……..………..61

Proximity to Water….………………………..…..62

Proximity to Roads and Trails…………..…..……..63

MANAGEMENT IMPLICATIONS……………………………..…....66

LITERATURE CITED…………………………………………………...….70

APPENDICES…..…………………………………………………………75

LIST OF APPENDICES

Appendix

1 Winter range plant list for Western Hemlock zones…………………………......76

2 Summer range plant lists for Pacific Silver and Mt. Hemlock zones………......77

3 Batch fixed kernel density for ten GPS collared elk at the 50, 90 &95% range area……………………………………………………………………………78

4 Habitat attributes and distances classes for habitat use analysis of female elk in southwest Washington………………………………………………………..84

5 All elk. Radio frequencies, capture dates and total number of locations of radio-collared elk in southwest Washington 2004-2008………..……………………..86

6 Elk name, life home range area, and migratory status of radio-collared elk in southwest Washington, 2004- 2008……………………………………..……87

7 Habitat use of aspects by elk in the combined Randle and Packwood study areas at the 50% and 95% range scales in the Southwest Cascades of Washington. 2007-2008……………………………………………………………………….89

8 Habitat use by elk relative to distance to cover in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……..91

9 Habitat use by elk relative to distance to shrub/scrub in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008………………...………………………….92

10 Habitat use by elk of slopes in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008…………………………………………………………………..…..93

11 Habitat use by elk relative to distance to water in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……………………………………...…94

12 Habitat use by elk relative to distance to paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……………………………………….95

13 Habitat use by elk relative to distance to non-paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008…………………………….96

14 Habitat use by elk relative to distance to trails in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……………………………………….97

15 R^2 values for Individual elk by habitat attribute at both the 50% and 95% scales…………………………………………………………………..……98

16 GPS collared elk data points per migratory status in the Randle subunit study area……………………………………………………………………..101

LIST OF FIGURES

Figures

1 Study Area for elk in the Southwestern Cascades of Washington……………..9

2 Batch fixed kernel density for Elk #30 at the 50, 90 &95% range area………...14

3 Packwood elk habitat analysis area…………………………………………..16

4 Randle elk habitat analysis area………………………………………..……..18

5 GPS collared elk data points per migratory status in the Packwood subunit study area..23

6 Elk distribution in the Packwood study area……………………………………25

7 Elk distribution in the Randle study area……………………………..………...27

8 Activity of migratory and non-migratory elk in the combined Randle and Packwood study areas in the Southwest Cascades of Washington. 2007-2008…………………………………………………………………….….29

9 Distance to cover analysis for migratory and non-migratory elk at the 50% scale in the Southwestern Cascades of Washington……………….………………….33

10 Distance to cover analysis for migratory and non-migratory elk at the 95% scale in the Southwestern Cascades of Washington………………………….……….36

11 Distance to shrub/scrub analysis for migratory and non-migratory elk in the Southwestern Cascades of Washington………………………...……………39

12 Migratory elk habitat selection with slope analysis………………………..…...43

13 Non-migratory elk habitat selection with slope analysis………………...……...43

14 Migratory and Non-migratory elk habitat use and distance to roads in the Southwestern Cascades of Washington…………………………………………48

LIST OF TABLES

Tables

1 Minimum Convex Polygon (MCP) home range estimates for migratory and non-migratory elk for years 2004 – 2008 and life home range comparisons for Western Washington elk in the upper Cowlitz River valley……………………21

2 Overall annual habitat use of aspects by elk in the combined Randle and Packwood study areas at the 50% and 95% range scales in the Southwest Cascades of Washington. 2007-2008……………………………………………30

3 Overall annual habitat use by elk relative to distance to cover in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……………………………34

4 Overall annual habitat use by elk relative to distance to shrub/scrub in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……………………….37

5 Annual overall habitat use by elk of slopes in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……………………………………..…..41

6 Overall annual habitat use by elk relative to distance to water in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008………………...……….….45

7 Overall annual habitat use by elk relative to distance to paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008……………………..….…47

8 Overall annual habitat use by elk relative to distance to non-paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the SW Cascades of Washington, 2007-2008……………………………….….49

9 Overall annual habitat use by elk relative to distance to trails in the combined Randle and Packwood study areas at the 50% and 95% range scale in the SW Cascades of Washington, 2007-2008……………………………………………...52

INTRODUCTION

Habitat loss is one of the biggest challenges wildlife species face worldwide. Conservation of elk (Cervus elaphus) winter range in particular continues to be a challenge to wildlife managers nationwide. Since the 1960s there has been a dramatic increase in human occupation of elk range in Western Washington State (U.S.A.), and most notably those geographic locations supporting elk winter ranges at lower elevations (Lyon and Christensen 2002). Conservation of winter range is critical for the sustainability of elk herds globally. Examining the way migratory and non-migratory elk use habitat may provide valuable insight into planning conservation efforts for the entire herd.

Differences in habitat use between migratory and non-migratory elk within the same herd are poorly understood both globally and locally. The literature includes a vast volume of studies on elk behavior while very few, if any, describe migratory and non-migratory elk behavior within the same herd.

Prior research has identified a need for herd-specific studies to be conducted on habitat selection of elk (Holthausen et al. 1994). Research gaps include information on the movements and wintering areas of the South Rainier elk herd (WDFW 2002). Movement patterns inside Mt. Rainier National Park have been described (WDFW 2002). However, movement patterns of elk living outside the park are poorly understood (WDFW 2002). A better understanding of winter range habitat use is important in order to: 1) identify areas to pursue for elk conservation in the most conflict prone area of the winter range via land acquisition and conservation easements, 2) assess potential impacts of increased development (e.g., along the upper Cowlitz River) and modified Forest practices in the Gifford Pinchot National Forest (WDFW 2002), and 3) identify whether impacts are likely to affect migratory, non-migratory, or all segments of the herd.

This thesis will provide habitat use analysis for both summer and winter range areas in the Packwood and Randle areas of Lewis County in Washington State, and will also examine the habitats and behavior of migratory vs. non-migratory elk. In this study, I used four population metrics to analyze and compare the South Rainier elk herd. I will address migration, fidelity, home-range, and survival, as indicators of stability, demography, and movement. The intention of this thesis is to provide herd-specific habitat use data to fill an existing research gap for the South Rainier elk herd.

I will explore differences in resource selection between and among migratory vs. non-migratory female elk by analyzing habitat use areas of South Rainier female elk at the core (50% contour level using a fixed kernel approach)) and home range (95% contour level fixed kernel). The major goals of this study are to: 1) compare and analyze home range areas of migratory and non-migratory elk in the study group; 2) compare and analyze winter and summer range use areas of migratory and non-migratory elk in the study group; 3) compare and analyze rates of pregnancy and mortality (where sample size is large enough) of migratory and non-migratory elk in the study group; and 4) describe herd dynamics and habitat use. Based on previous studies in other systems, I hypothesize that habitat use and home range size between migratory and non-migratory elk will be significantly different. The intent of this study is to identify and describe any differences in habitat usage between, and among, migratory and non-migratory elk at both home-range, and the 50% and 95% MCP use areas within the greater home range on both summer and winter range. Based on my findings, I will recommend management strategies, and help to identify future research needs.

HISTORY

In the state of Washington, 10 distinct elk herds (*Cervus elaphus*) have been identified as inhabiting various regions of the State. The native elk that were historically found in greater Washington State have been identified as the subspecies Roosevelt elk (*Cervus elaphus roosevelti*). The historic range of the Roosevelt elk subspecies extended from just North of San Francisco, CA to Vancouver Island, BC, and inland from the Pacific Ocean to the Cascade Mountains (O'Gara 2002). The current range includes the coastal areas of Humboldt and Del Norte counties, CA, northward through western Oregon and Washington to Vancouver Island (O'Gara 2002). Historic, archeological, and anthropologic records support evidence of substantial numbers of elk in Washington State prior to European exploration and settlement at the start of the 19th century (Schullery 1982). By 1900, much of western Washington (with the exception of the Olympic Peninsula) was devoid of elk. In many instances, native elk were thought to have never existed in areas such as the Mt. Rainier National Park area (Bradley 1982). Elk in the Cascade Range of Washington were eliminated to the extent that many early settlers, explorers, and their descendents held the belief that elk were not a native species of the area.

Historic records not only affirm the presence of elk in Washington State prior to European settlement, but also include documentation of Native Americans relationship with elk. Some examples of the subsistence and cultural importance of elk include uses of elk horn by the Puyallup and Nisqually Tribes to make clubs, elk horn wedges to split cedar planks, elk and deer hides to wrap bodies for burial, the use of untanned elk skin to make “parfleches” that were used as containers, and consumption of elk for sustenance (Haeberlin and Gunther, 1930). Members of the Puyallup Tribe were known to hunt and to use fire to manage for deer and elk habitat in the area surrounding Mt. Rainier (Schullery 1984). Puyallup Tribal groups also travelled annually to Mt. Adams, Mt.St. Helens and various other mountain regions throughout the state for annual huckleberry picking, and hunting of deer and elk during late summer and early fall (Powatten Mills, personal correspondence). Camps were set up for the duration of the annual berry picking and associated hunting in the Mt. Adams, St. Helens, and Indian Wilderness areas. Thompson also documents local tribal activity around Mt. Rainier as centered on hunter-gatherer camps near important huckleberry fields at an altitude between 3,000 and 5,000 feet (Thompson 1981). Trade routes were used by Puyallup members throughout the state. A primary route used to connect to the east side of the Cascade Mountains was the Naches Trail. It was also common practice for Tribal members to engage in hunting of deer and elk while travelling. Inter-tribal marriages were also common. These further strengthened bonds amongst Tribes within the region. The Packwood Pass area, which extended up the Ohanapekosh across to the Cowlitz Divide that flanks the south and east sides of Mt. Rainier, was regarded by local tribes as some of the very best hunting grounds (Schullery 1982, Brown 1920). The presence of native elk and their associated cultural significance to local tribes may therefore be considered to be well established.

Rocky Mountain elk (*Cervus elaphus nelsoni*) is a North American subspecies of elk whose range includes the Rocky Mountains and adjacent mountain ranges, from the 55th parallel southward to the 35th parallel (O’Gara 2002). At the turn of the 20th century natural resource managers established new policies and regulations to aid in re-establishing the extinct elk herds. This led to Rocky Mountain elk being introduced to the area around Mt. Rainier, starting in the early 1900s. The intent of the introduction of Rocky Mountain elk by game managers was to supplement existing remnant populations of native elk, and to re-establish elk where they had been extirpated. Also, by the 1950s, forest practice changes such as extensive logging in the Cascades around Mt. Rainier

National Park (MRNP), also helped created habitat conditions favorable to elk. This further boosted local elk populations. Elk herd numbers began to steadily grow. A census survey conducted by the U.S. Forest Service in September 1962 counted 466 elk along the eastern border of Mt. Rainier National Park (Schullery 1982, Bender 1962). At the time, elk were still believed to be very scarce. Park managers not only believed that very few elk resided in the Park; but they were also under the impression that MRNP could not possibly support that many animals (Schullery 1982, Bender 1962). Park managers were skeptical of the elk count, and they conducted their own survey of the same general area on October 16, 1962. This survey found between 25-30 animals, which did not support the numbers from the previous survey (Schullery 1982, Bender 1962).

However, Gilbert and Moeller (2008) have shown elk movement across the landscape to be temporally and spatially dynamic. It is not uncommon to observe dramatic shifts in habitat use during the onset of the rut (breeding season) in September, and the rut in October. Elk also have a tendency to use habitat with cover more frequently during the rut than during the time period leading up to the rut. Typically, elk will tend to be in larger groups in open landscapes (IE: alpine meadows, shrubs) prior to the rut. During the rut, the elk tend to fragment into smaller breeding groups. These groups are frequently found in timber in the sub-alpine areas, which make them more difficult to detect. With a greater understanding of elk ecology, the disparity in elk counts between a September and October survey in 1962 is not surprising.

By the 1970s, Washington State Department of Fish and Wildlife (WDFW) identified ten separate elk herds in Washington State. The South Rainier elk herd is one of those 10 herds identified, and is the focus of this thesis. Since the mid-late 1900s, estimates of herd numbers have dramatically fluctuated based on forest practices, development, and legal and illegal hunting. As already mentioned, extensive logging in the mid-1900s created large gaps in the forest canopy that stimulated growth of preferred elk browse species such as: *Vaccinium* sp., *Rubus* sp., Salal (*Galtheria shallon*) Red elderberry (*Sambucus racemosa*), Sword fern (*Polystichum munitum*), and Bear grass (*Xerophyllum tenax (Pursh) Nutt)*. With the improved habitat conditions for elk, the carrying capacity in the area likely increased. Elk herd numbers may have increased in turn. With larger numbers of elk, and the use of less accurate methods for estimating the numbers of elk, regulations were formulated that allowed extensive harvest of both males and females of the population. Recent examples of the fluctuating South Rainier elk herd numbers include the 1994 WDFW herd estimate of approximately 3,800 animals, followed by an estimate in 1998 of only 1,700 animals (WDFW 2002). Liberal state hunting regulations which included unlimited cow harvest in the mid-1990s (typically used to reduce population numbers) were employed and resulted in a dramatic reduction of the population. Current population estimates are made annually in spring of each year by the Puyallup Tribe. The 2009 estimate was 1,000 animals.

The Puyallup Tribe of Indians are signatory to the Medicine Creek Treaty of 1854. The Treaty guaranteed the Tribe the right to hunt on open and unclaimed lands. The primary stock of elk currently harvested by the Tribe for ceremonial and subsistence purposes is the South Rainier elk herd. As a sovereign nation, the Tribe manages their own resources for wildlife, and sets hunting and harvest regulations based on the best available science. To better estimate herd numbers, a computer model for estimating elk abundance, and to monitor population trends was developed by the Puyallup Tribe (Gilbert and Moeller, 2008). The Tribe conducts annual surveys to collect the raw data to be used in the computer model for population estimates. The population estimates are used to steer the hunting season and regulation setting process for the South Rainier herd. Since 2004, the Tribe has raised approximately $1,000,000 in grant (USFWS and BIA) and tribal funding for resource management activities benefitting the South Rainier elk herd. Management activities include: habitat improvement projects on winter and summer range, land acquisition for elk conservation, population model development, aerial surveys, mortality/survival estimates, and VHF and GPS collaring of elk.

Migration

Migration can be defined as animal movement, usually periodically, from one region or climate to another for feeding or breeding (Skovlin et al. 2002, Gove 1969). Kennedy provided a behavior-oriented definition of migration as: *Migratory behavior is persistent and straightened-out movement effected by the animal's own locomotory exertions or by its active embarkation on a vehicle. It depends on some temporary inhibition of station-keeping responses, but promotes their eventual disinhibition and recurrence* (Kennedy 1985). A variety of elk migratory behaviors have been observed and well documented with associated hypotheses explaining the behavior. Some of the variations in elk migration include: elk that do not migrate; migration in response to changes in forage conditions (Irwin 2002, Graf 1943); and true migration described as *migrations as changes of habitat, periodically recurring and alternating in direction, which tend to secure optimal environmental conditions at all times* (Thomson 1926 pp 3). Examples of elk movement that have been observed but have not been considered true migration have been differentiated by factors such as: 1) summering areas often are accessible during winter; 2) movements are not consistent among herds; and 3) the timing of movements differs among herds (Irwin 2002, McCullough 1969).

Once the migration status of elk based on an established definition of migration has been determined, variations in migration are still common between and among regions, sex, and age class of elk, in addition to differences between pregnant and barren cows (Irwin 2002). Temporal and seasonal variations also influence migration and timing of migration. Indentifying differences in how migratory and non-migratory elk use the landscape is important in understanding patterns of habitat use.

Elk migration may be also viewed as dynamic with regard to animal response to anthropogenic influences. An example of this is non-migratory segments of populations that have been culled, thus reducing actual numbers of the population that would represent non-migratory behavior. In many areas, overall patterns of migration have been obscured because of this type of culling (Irwin 2002). Other examples of elk response to human influence have been where elk find protection afforded by national parks or refuges on summer and transitional ranges, and they tend to stay within those sanctuaries until the hunting season is over or they are driven down by deep snow (Lovaas 1970, Picton and Picton 1975, Brown 1985). Rocky Mountain elk have also been known to have changed their migration routes in response to human settlement and hunting (Boyce 1989).

Fidelity

Fidelity is the tendency of an animal either to return to an area previously occupied or to remain within the same area for an extended period of time (White and Garrott 1990). In many cases, it is commonly believed that there is substantial variation in migratory patterns of elk between years. Specifically, the theory held is that there are increasing numbers of elk year-to-year that have changed their migratory pattern to a non-migratory habit based on natural selection. In general, female offspring tend to establish ranges in or adjacent to their mother's social group (Raedeke et al. 2002). Many studies have reported strong philopatry of female elk for seasonal and annual ranges (Craighhead et. al. 1972, Rudd et al. 1983, Edge and Marcum 1985, Edge et al. 1986, Smith and Robbins 1994, Raedeke et al. 2002). Strong fidelity, tradition, and learned behavior among cow elk likely contribute to the stability of social groups (Raedeke et al. 2002, Edge et al. 1986, Van Dyke et al. 1998.).

Home Range

Home range is considered the area that is traversed by the individual in its normal activities of food gathering, mating, and caring for young (Burt 1943: 351). *Normal activity* is commonly accepted as 95% of the locations of an animal within the entire home range area (White and Garrott 1990). Home range may be measured using a variety of different methods yielding varying results. Understanding home range, and the various aspects of home range, such as variation in range areas between migratory and non-migratory elk is very important. Baseline knowledge of critical core habitat areas should be understood before attempts are made to improve existing habitat conditions to benefit elk herds. In the current study, much of the land use in the winter range area is potentially not compatible with the presence of elk. Complaints are made annually and include summer crop damage and livestock fence damage by elk (WDFW Elk Nuisance Report 2008). Conflicts between land owners and elk occur throughout the year within the study area (WDFW Elk Nuisance Report 2008). However, elk learn easily from their experience, and may adjust their ecology and behavior accordingly (Geist 1982). By using data based management strategies, conflicts on winter range could be reduced and/or mitigated. Exploring differences at the 50% and 95% MCP scales between migratory and non-migratory elk may yield results that enhance understanding of how elk use the landscape depending on their migratory status.

Cow Survival

Annual survival estimates on the reproductive portion of an elk population are important in managing for sustainable populations of elk. Survival rates may be used to steer management strategies for the specific herd. Pregnancy rates are also an important measure of the health of an elk herd.

STUDY AREA

Location

The study area includes both summer and winter ranges of the South Rainier elk herd. Winter range is associated with the upper Cowlitz drainage near the towns of Packwood and Randle, in eastern Lewis County of Washington (Figure 1). Summer range areas are bordered by the Cascade Range crest to the east, Mt. Rainier to the North, the Goat Rocks Wilderness Area to the southeast, Mt. St. Helens to the southwest, and the eastern shores of Riffe Lake to the west (Figure 1). The entire study area encompasses approximately 1,028 km^2 (102,841 ha). Land ownership is made up of primarily public land (Gifford Pinchot National Forest, Mount Rainier National Park (MRNP), Mt. St. Helens, Washington State Department of Natural Resources (WADNR), WDFW), some industrial timberlands (Port Blakely), land held by the Puyallup Tribe of Indians, and a small percentage in private land ownership. The majority of critical winter range is located on private land. The entire study area is located within the Medicine Creek Treaty traditional use area.

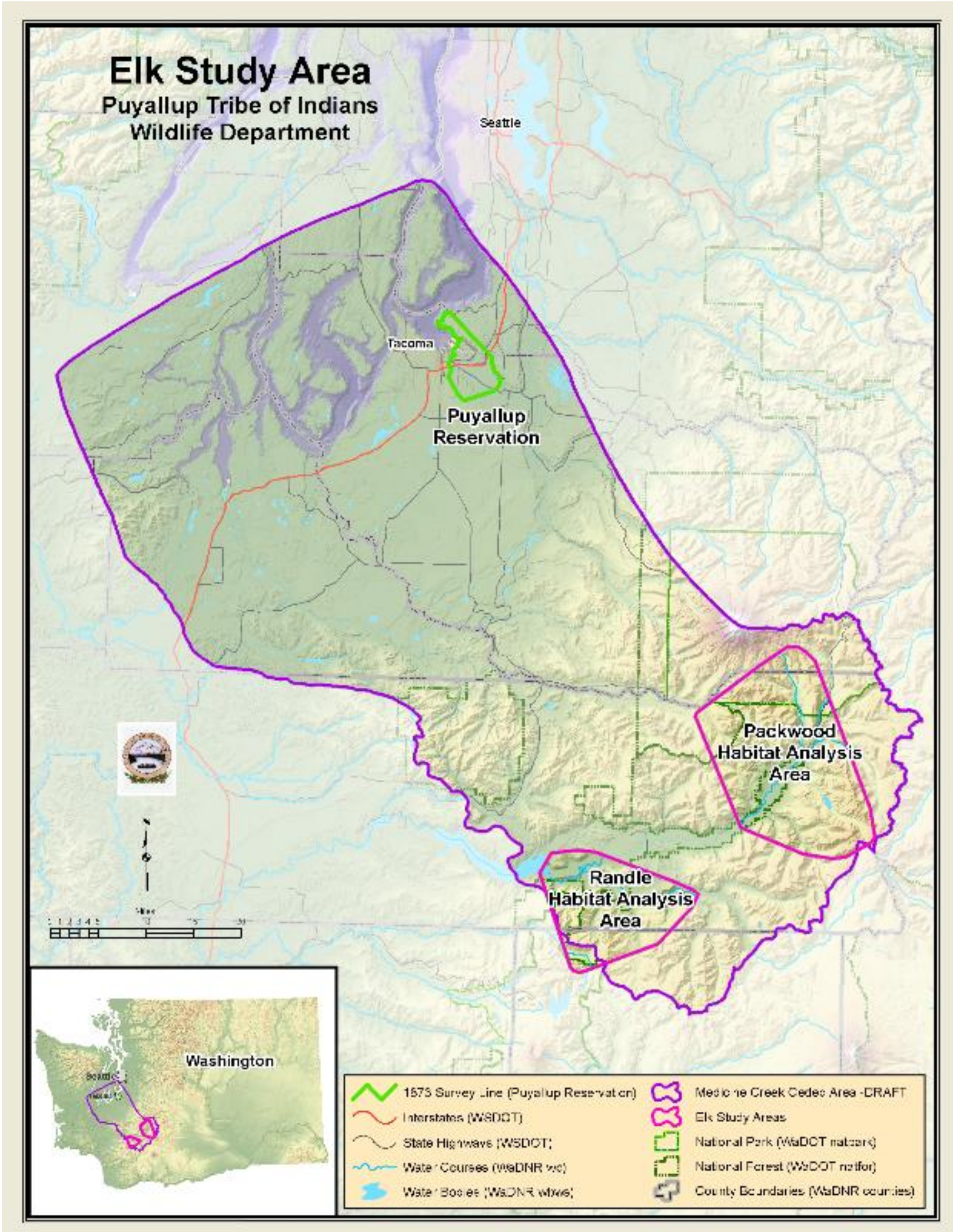
Climate

This sub-region is categorized as a temperate maritime climate which typically experiences hot dry summers and cool, wet winters. Annual precipitation ranges between 1.47 m (57.8 in) in the low elevation areas and 3.2 m (126 in) in the higher elevation areas of the range (National Weather Service 2010). Average annual temperature in the Packwood area is 9.67° C (49.7° F) (National Weather Service 2010). Years 2008 and 2009 experienced La Nina conditions, which resulted in cooler than normal temperatures, and higher than normal levels of precipitation. Both 2008 and 2009 experienced >1 m (3 ft) of snow on winter range for more than 2 months. Typically, snow accumulation on winter range does not exceed 0.3m (1 ft) and usually melts within 2 weeks (National Weather Service 2010).

Topography and Vegetation: Winter Range

Topography in the winter range area is flat to rolling in the river bottoms but increases steeply in the uplands. The area is dominated by dense coniferous forests of Douglas-fir (*Pseudotsuga menziesia*) and Western hemlock (*Tsuga heterophylla*) in the uplands, open agricultural and rangelands in the valley bottom, and open hardwood galleries dominated by Big leaf maple (*Acer macrophyllum*), Black cottonwood (*Populus trichocarpa*) and Red alder (*Alnus rubra*) along the river floodplain (Gilbert and Moeller, 2008). Elevation in the winter range area ranges from 300 m to 2,100 m. The non-migratory elk in the herd remain

Figure 1. Study Area for elk in the Southwestern Cascades of Washington.



generally in the winter range area. The range of the herd falls within the Southern Washington Cascades Province (Franklin and Dyrness, 1973) and the winter range area generally falls within the Western hemlock (*Tsuga heterophylla*) zone (Franklin and Dyrness, 1973). Detailed plant zone tables are located in Appendix 1.

As stated above, a very small proportion of winter range is within public ownership (WDFW 2002). Much of the river bottom areas on winter range include land uses such as agricultural, private timberlands, recreational/undeveloped lands. A smaller portion of winter range is residential. Human tolerance for elk in these areas is mixed. Since 2004, local and state jurisdictions on average have received 15 nuisance/damage complaints annually. In many cases, the State has allowed special hunts during winter, which has targeted antlerless elk where chronic problems persist. Tribal and state managers agree that lethal removal of elk is not a long-term solution for nuisance complaints but the hunts have served to ease local tension and political pressure.

Topography and Vegetation: Summer Range

Summer range forest zones include the Western hemlock (*Tsuga heterophylla*) zone, the Pacific silver fir (*Abies amabilis*) zone, the Mountain hemlock (*Tsuga mertensiana*) zone, the upper parkland subzone, and the Alpine zones (Franklin and Dyrness, 1973). The topography in the mid-elevation areas up to the alpine, are moderate to steep in most areas. The elevation range spans between 305 m – 1,829 m (1,000 ft – 6,000 ft). Detailed summer range plant zone tables are located in Appendix 2.

Land ownership on summer range areas for the migratory elk in the study group primarily consists of public lands that include MRNP, Gifford Pinchot National Forest, and Mount Saint Helens National Monument. Approximately, 66% of the wintering herd is migratory. Approximately 34% of the wintering herd(s) is non-migratory. The non-migratory segment of the respective herd is responsible for the damage complaints by farmers that occur over the summer months. Crop damage is a common complaint filed with local and state jurisdictions. In response, numerous damage/kill permits for antlerless elk are issued during the month of August. As a result, cow elk with dependent calves (2 months old) are likely removed as a part of these damage hunts. Overall patterns of migration of elk may be obscured by exposure to hunting (Irwin 2002). This type of management is a cause for concern because it potentially alters the understanding of elk migration.

METHODS

The Puyallup Tribe began the first phase of research, conducted between 1999 and 2000, and placed 36 radio collars on female elk in the study area. At that time, the wildlife staff was interested in learning more about the ecology of the South Rainier elk herd. Some areas of interest included: migration patterns, timing of migration, herd fidelity, and information on calving areas. Analysis of data in that phase of research was not completed. After a gap of two years, the research was continued under subsequent United States Fish and Wildlife Service and Bureau of Indian Affairs Grants. Since then, the Tribal Wildlife Program has maintained approximately 30 cow elk fitted with Very High Frequency (VHF) radio-collars. Cursory analysis of the data has been completed by the Tribal Wildlife Program (Puyallup Tribe USFWS grant report).

As a result of initial data analysis and population modeling work (Gilbert and Moeller, 2008), multiple habitat improvement projects have been funded and land acquisition for elk conservation on winter range has been completed. In 2004, the Tribe used relocations from the radio-collared elk to begin work on development of a computer model (Gilbert and Moeller, 2008) to provide an alternative method for determining elk numbers due to changes in forest management that made the current methods for estimating elk abundance unreliable in the more heavily forested areas.

Bureau of Indian Affairs (BIA) funding for 4 GPS collars and associated equipment was awarded to the Tribe in 2007. Those collars were deployed on 4 adult cow elk in March 2007. USFWS funding for 11 GPS collars was awarded to the Tribe in 2008. Those collars were deployed on 11 adult cow elk in March 2008.

Elk Captures

In order to place collars on elk, each animal was remotely darted from a Bell 206 B3 (Jet Ranger) helicopter with a Carfentanil citrate (ZOOPHARM, Laramie, Wy) - Xylazine hydrochloride (Webster Veterinary Supplies) drug combination during March 2004-2008. During capture efforts, we attempted to select adult cow elk evenly across the winter range area to avoid oversampling of specific social (family) groups. While the elk were concentrated on winter range, there was no way of knowing the migratory status of the captured elk until the onset of the following summer migration. The Carfentanil citrate-Xylazine hydrochloride drug combination was reversed using Naltrexone (Anazao Health, Amarillo, TX) and Yohimbine (Anazao Health, Amarillo, TX) once the animal was processed. The darting crew, consisting of two people, were dropped off near the darted elk and began processing the elk by blindfolding, hobbling, and collecting body temperature readings. The capture crew of four people were shuttled by the helicopter to a location near the darted elk. The capture crew then completed processing the darted elk. Each animal underwent the following procedure: Dart removal, fitted with a GPS or VHF radio-transmitter collar, blood drawn and sent to lab for pregnancy, disease, and DNA analysis, body condition assessment, age estimation based on dentition wear, fecal sample collected for parasite testing, vaccination with antibiotics and vitamin injections. Age estimates made by the capture crew were based on patterns of tooth eruption and wear (Quimby and Gaab 1957). The average time the animal was immobilized was approximately 15 minutes. A veterinarian with extensive elk capture experience was contracted to work on the captures.

Fecal and serum samples were prepared per veterinary sampling standards and shipped to Washington State sanctioned laboratories for testing. Disease testing included testing for the following suite of parasites and diseases: Brucellosis, Blue Tongue, *Coccidia*, Liver flukes, Lungworm, *Leptospira grippo*, *Leptospira Hardjo*, *Leptospira Ponoma*, *Leptospira ictero*, *Leptospira canicloa*, *Dictocaulus*, *Anapolysis*, *Strongyles*, and *Capillaria*. The elk we captured and collared in 2004 were also tested for gene stock. Samples were submitted to the WDFW laboratory

Each elk was either fitted with a mortality sensing radio-telemetry collar (MOD-500, Telonics Inc., Mesa, Arizona, USA), or a Spread Spectrum Global Positioning System (GPS) telemetry collar (Gen-3,SST, Telonics Inc., Mesa, Arizona, USA). The VHF collars had an estimated 3-year battery life. The GPS collars had an estimated 1-year battery life. The GPS collars were programmed to record fixes (Latitude and Longitude) 24 times a day at one-hour intervals while on summer and winter range. Fixes were recorded 4 times a day at 6-hour intervals during transitional periods in spring and fall. The collars were also engineered with an activity sensor that records the number of times the animal moves its head in a feeding posture over a 60-minute period 24 times each day. For example, if an animal moved its head 1-10 times in an hour it would be considered to be bedded/resting and/or ruminating. The collars were programmed to upload the data collected 2 times each week for a 4-hour period via the associated transceiver (Telonics Inc., Mesa, Arizona) and RAU software (Telonics Inc., Mesa, Arizona) loaded on a laptop computer. At the end of the data collection period, and towards the end of the unit's battery life, the GPS collars were programmed to release from the animals. The collars were then retrieved in the field.

Elk capturing was timed so there was no overlap of a hunting season for up to 30 days due to toxic levels of immobilization drugs. This ensured that no hunter would ingest any of the unmetabolized drugs. Collared elk did not receive exemption from being harvested during hunting seasons. Mortalities attributed to harvest were included in the study and documented and used in the survival analysis. The collars had contact information and drug warning information attached.

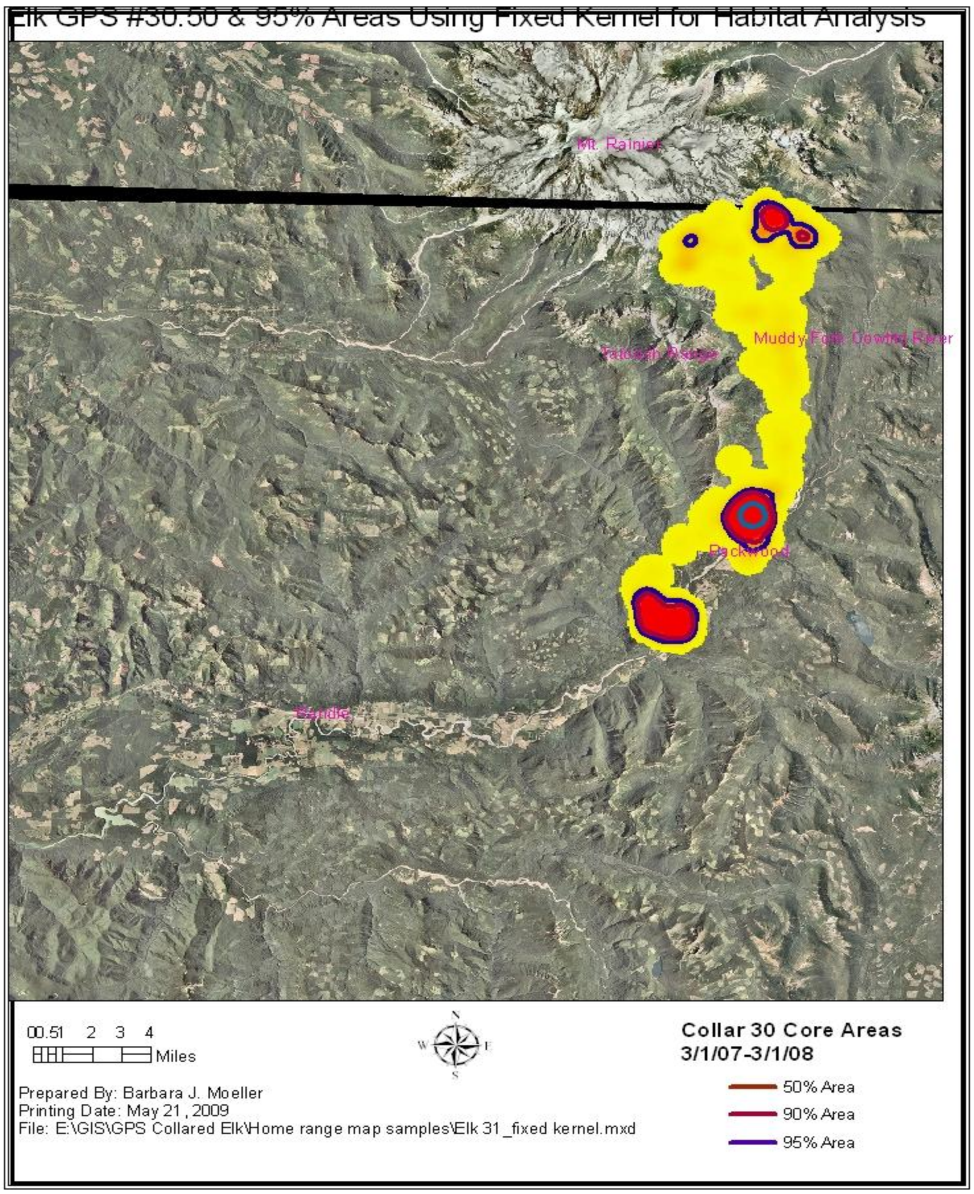
Radio-Telemetry

The battery of the conventional VHF collar was expected to last at least 36 months but often lasted for several additional years. Relocations were obtained 1-4 times per month. Relocations were obtained from a Cessna 172 aircraft fitted with 2-element H-antennas (Telonics, Mesa, AZ), using standardized methods described by Mech (1983). Most relocation surveys were conducted between 08:00 and 14:00 in an attempt to capture elk when they may still be active. VHF coordinates were recorded with a GPS receiver (Model Meridian, Magellan Corporation, Santa Clara, CA). VHF coordinates were evaluated for accuracy by comparing fixes marked with the hand-held GPS unit with the fix recorded on the GPS collar for the same day and time. Both the VHF and GPS collared elk were used for analysis in this thesis.

Home Range and Core Use Areas

Locations on a total of 53 unique radio-collared elk were used for home range analysis using the minimum convex polygon (Hayne 1949) estimator for overall home range of each individual elk, and an estimate for the average home range for the entire herd. The MCP estimator was also used to estimate home range area for each elk by biological year. The fixed kernel method was used for home range estimates for 15 GPS-collared elk (Figure 2 and Appendix 3). Home range estimates for the 15 elk at the 95% and 50% contour levels were generated using the fixed kernel method with the Hawthes Tools extension for ArcGIS (ArcGIS 9.3, ESRI Inc, Redlands, California, USA). Approximately 80,000 locations were collected on the GPS-collared elk during the study period. The large sample size allowed us to run the fixed kernel analysis on the GPS collared elk. Fixed kernel home range analysis was the preferred method since it provides a more accurate robust reflection of habitat use areas. However, the total number of locations per year, and life period, for the VHF-collared elk was substantially smaller. All data were normally distributed and had equal variance between groups. Paired t-tests (Microsoft Excel 2007, Microsoft, Inc. Redmond, WA) were used to determine significance in MCP home range estimates between migratory and non-migratory elk.

Figure 2. Batch fixed kernel density for Elk #30 at the 50, 90 &95% range areas.



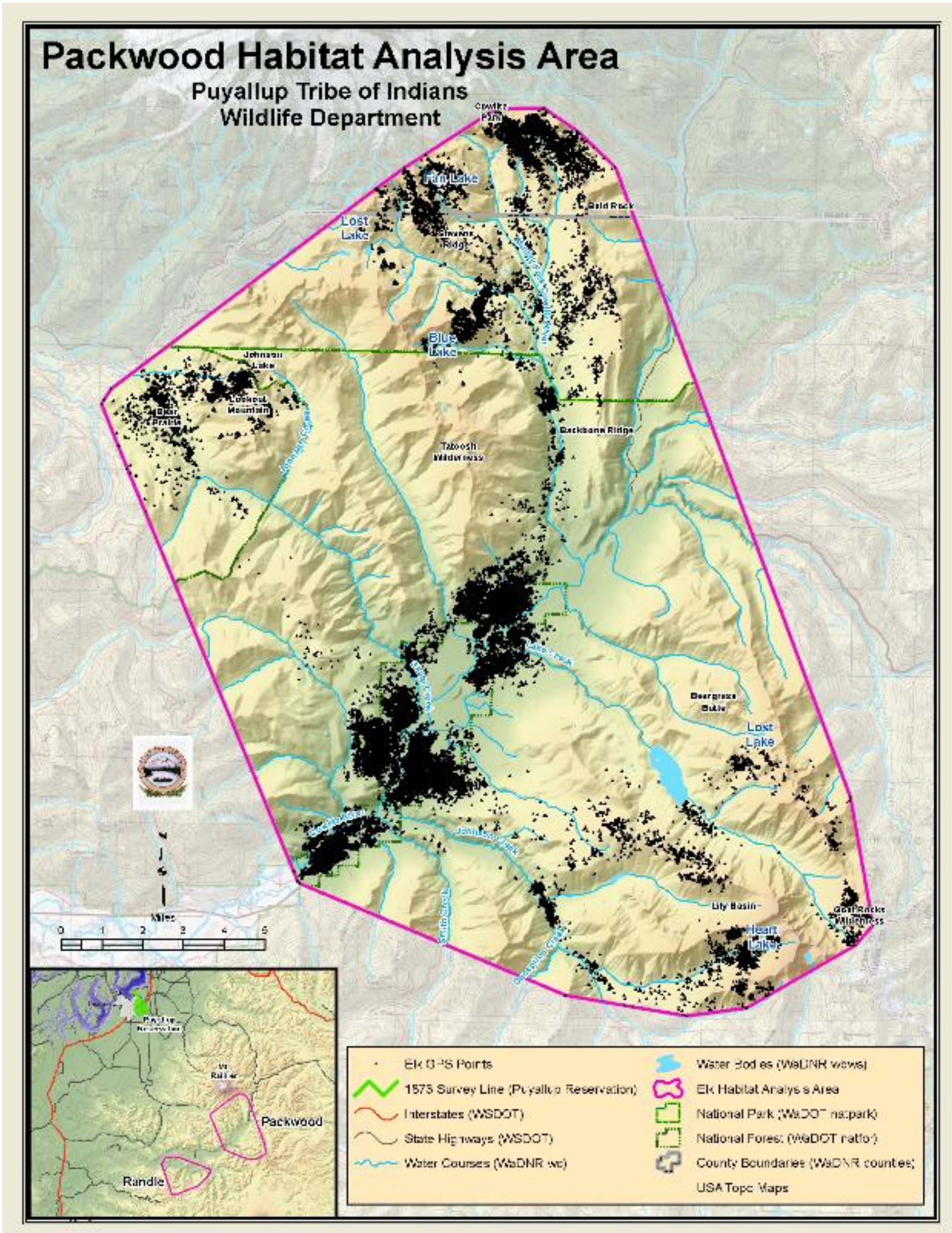
Cow Elk Survival

Cow elk survival rates were estimated for the radio-collared elk throughout the period of the entire study using the binomial distribution method (White and Garrott, 1990), and the Kaplan-Meier Method (Kaplan and Meier 1958) with the Pollock adaptation for staggered entry (Pollock et al. 1989). Estimates were made by biological year which spanned June 1 – May 31st of the respective year. Annual estimates of survival rates were made based on these data. No attempt was made to make annual survival estimates per migratory status of group because sample sizes would have been too small to provide meaningful information. Total number of migratory and non-migratory collared elk mortalities combined per biological year ranged from 3-10 per year.

Habitat Variables

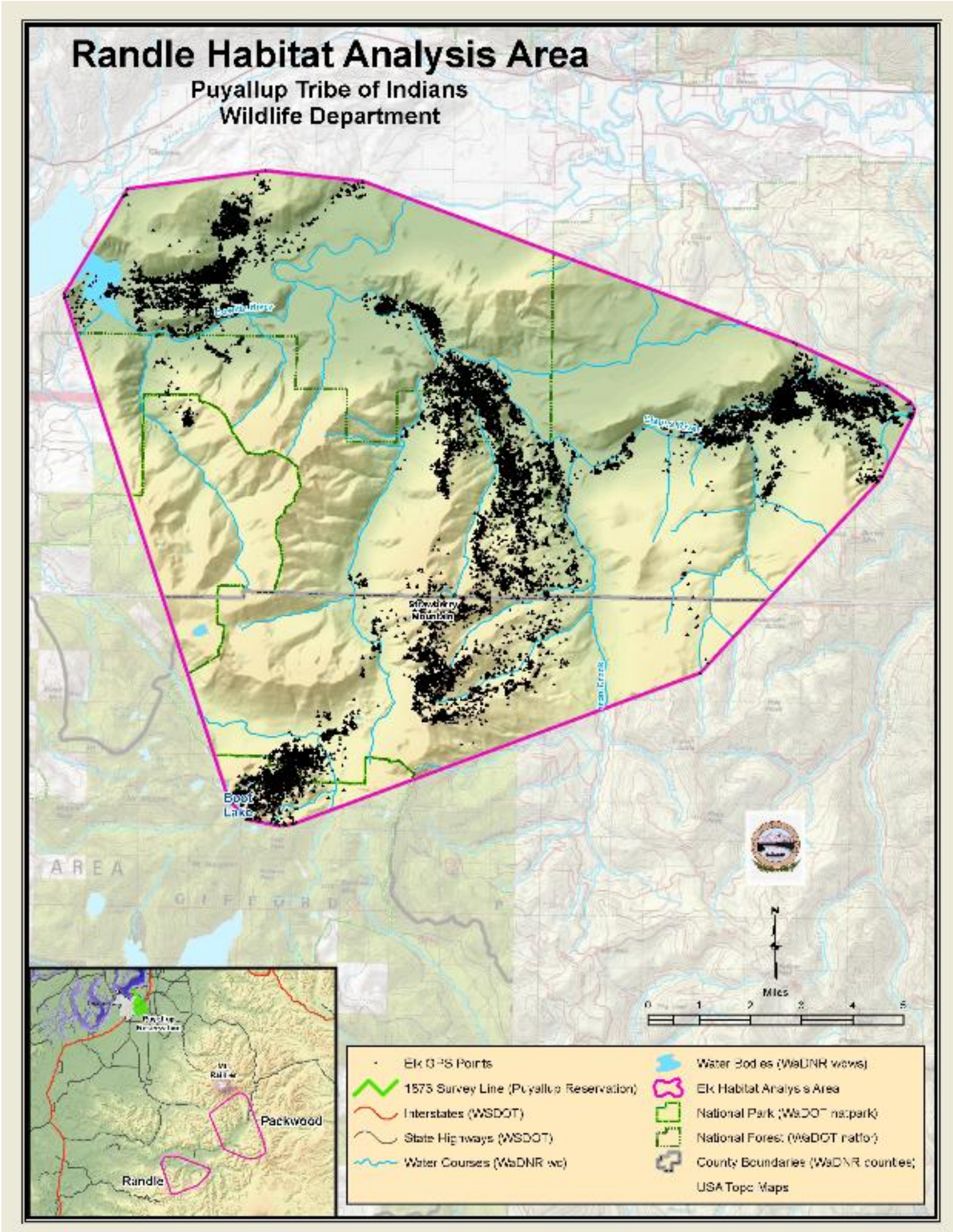
The study area boundaries were divided into two separate sub-units based on wintering locations of the sub-herds of the collared elk along the upper-Cowlitz river basin using the minimum convex polygon of all GPS collared elk locations. The GPS study group of elk consisted of 15 collared elk, four in the Randle unit and 11 in the Packwood unit. The 15 GPS collared elk yielded >80,000 data points. The two sub-units are referred to as the Packwood unit (679 km^2) located in the most easterly portion of the study area (Figure 3) and the Randle unit (349 km^2), located west of the Packwood unit, in and around the town of Randle (Figure 4). Habitat variables within each area included slope, aspect, distance from evergreen/cover, preferred forage (shrub/scrub, meadow, and pasture), presence of water, and roads. Slope and aspect layers were developed from 1:24,000 scale USGS 10 M Digital Elevation Model (DEM) data. Aspect was divided into four categories: east/northeast, north/northwest, south/southwest, and south/southeast. Slope was divided into five categories: 0-1% (flat), 1-15%, 16-30%, 31-45%, >46%.

Figure 3. Packwood elk habitat analysis area.



National Land Cover Data (NCLD) was obtained and used to create habitat maps of the study areas. Nineteen habitat variables were initially identified in the study areas. These were later reduced to seven categories to reflect closely related habitat attributes for analysis. As already mentioned, land type variables were divided into 7 major categories: shrub/scrub/meadow/pasture, evergreen forest (cover), water (to include riparian/deciduous areas), and roads. These categories represent critical habitat attributes that are commonly analyzed in elk habitat suitability studies (Thomas et al 1979, Lyon 1983, Bracken and Musser 1993). Distance class for each category ranged between 2-6 distance classes per habitat type (Appendix 4). For example distance classes to water, cover, and shrub scrub were: 0-50 m, 51-100 m, 101-200 m, 201-400 m 401-600 m, and >600 m. Distance class to roads and trails were: 0-100 m, 101-200 m, 201-400 m, 400-600 m, and >600 m. Paved roads included only 2 distance classes which were 0-600m and >600m to roads. Distance classes used in our study were modeled after standard distances classes used in other elk habitat analysis studies (Skovlin et.al 2002).

Figure 4. Randle elk habitat analysis area.



Once the habitat variables were selected, the land cover data set was ground truthed by comparing aerial digital orthophotos to the land cover image/data set. The entire image/data set was edited using the aerial orthophotos until a final image was produced that most accurately reflected current habitat conditions of the study area. Stream and road layers were obtained from the United States Forest Service (USFS), Washington State Department of Natural Resources (WADNR) Lewis, Pierce, Yakima, and Skamania Counties. Distance from GPS locations to the selected habitat features were analyzed by using the near-analysis tool in the ArcGIS toolbox (ArcGIS 9.3, ESRI Inc. Redlands, CA, USA) for proximity-to-features tool.

Habitat Use, Seasonal Habitat Use, and Time of Day

Habitat use and distances from roads, water, cover, and shrub/scrub were analyzed at two spatial scales: 95% fixed kernel, and 50% fixed kernel. Paired t-tests (Microsoft Excel 2007, Microsoft Inc. Redmond, WA) were used to determine if habitat use varied between individual elk, and between migratory and non-migratory groups beyond the range that would be expected by chance. Data were analyzed using a student's t-test with $p \leq 0.05$used to denote significance. Analysis where $p=0.10$ were also included in the analysis to provide supplemental insight into the primary analysis. The t-tests in this study identify areas where the habitat selected by the elk occurred beyond the range that would be expected by chance. The focus of this study analyzed differences between migratory and non-migratory groups of elk. Differences between individual elk were included in the study, but they were not examined in detail.

Seasonal and time of day variables were also evaluated in the analysis. Elk locations were divided into four biologically significant seasons: Spring/calving (March-June), Summer (July-August), Fall/rut (September-November), and Winter (December-February). Time of day was also evaluated, and divided into four intervals based on observed activity: dawn (0500-0900), diurnal (0900-1700), dusk (1700-2100), and nocturnal (2100-0500). Ordinal regression (SPSS 17.0, SPSS Inc., Chicago, Ill) was used to determine whether season and season and time of day influenced habitat use between individual elk and/or migratory versus non-migratory elk. The data set used for the elk study had taken the physical distances of the elk from given land features (scaler variables), and grouped then into distance classes (becoming ordinal variables). It was therefore necessary to conduct ordinal regression (as opposed to linear or non-linear regression) in modeling the behavior of the elk. Ordinal regression in SPSS allows a choice from among five different link functions (mathematical transforms) to optimize the fitting to the data, and calculates a pseudo R^2 as a rough estimate of the probability of picking the correct distance class for a given individual elk, or group of elk, given the season and/or time of day.

RESULTS

Elk Captures

Fifty-three elk were captured and radio-collared during the month of March in years 2004-2008 respectively. Thirty-nine VHF collars were deployed years 2004-2007, 4 GPS collars were deployed in 2007. The final 11 GPS collars were deployed in March 2008 (Appendix 5). All cow elk were determined to be in relatively good condition by the project veterinarian (Briggs Hall, DVM) with the exception of the elk captured in 2008. The elk captured in 2008 were in below moderate - poor condition due to unusually harsh winter conditions (National Weather Service 2010). Special note of significance were two GPS collared elk mortalities, for which the cause of mortality was unknown, which occurred in May of 2008. Consequently, the bulk of the data that were available for habitat use analysis via the GPS data was reduced to 13 GPS collared elk.

No diseases were detected. Genetic testing indicated that the elk were a hybrid mixture of Rocky Mountain elk (*C.e. nelson*: translocated elk) and Roosevelt elk (*C.e. roosevelti*: native to WA).

Home Range

Home range estimates were made using 53 elk starting where there were > 10 locations (Appendix 6). Comparisons of mean home range size between migratory and non-migratory elk groups per biological year demonstrated differences between the groups per biological year (Table 1). Life home range also demonstrated differences between the migratory and non-migratory elk (Table 1).

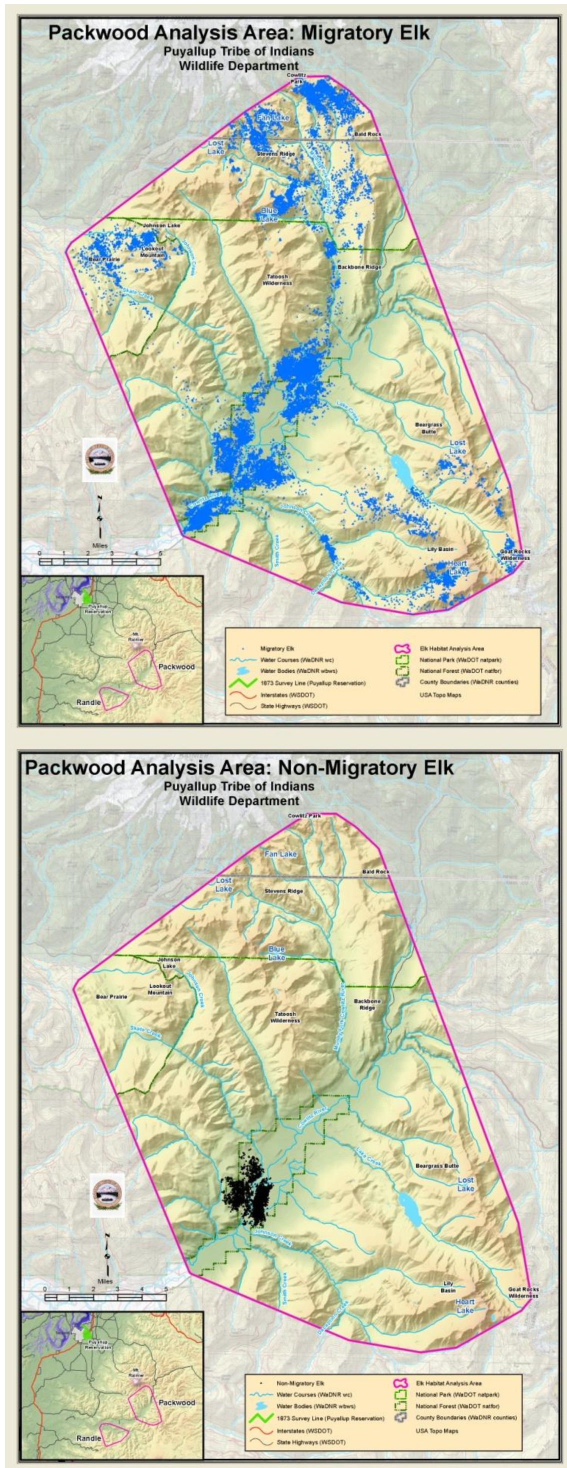
Table 1. Minimum Convex Polygon (MCP) home range estimates for migratory and non-migratory elk for years 2004 – 2008 and life home range comparisons for Western Washington elk in the upper Cowlitz River valley.

Year	Migratory Status	Mean MCP Km^2 Area	Mean MCP Hectares Area	Sample size (N)
2004	Non-migratory	8.4	840	3
2004	Migratory	58	5800	14
2005	Non-migratory	5.4	540	7
2005	Migratory	54	5400	15
2006	Non-migratory	11	1100	5
2006	Migratory	54	5400	23
2007	Non-migratory	11	1100	8
2007	Migratory	55	5500	27
2008	Non-migratory	14	1400	8
2008	Migratory	75	7500	24
2004-2008	Non-migratory	20	2000	18
2004-2008	Migratory	102	10200	36
2004-2008	Combined	61	6100	54

Home range size was estimated using the Minimum Convex Polygon (MCP) where the mean area for all elk was 6100 ha (61 km^2). Whereas MCP mean for migratory elk was 10200 ha (102 km^2) and 2000 ha (20 km^2) for non-migratory elk.

Differences were detected between migratory and non-migratory elk for MCP home range estimates both by individual biological years (BYR), and at the life home range area scale. Significant differences were detected in BYR 2005 in MCP home range estimates between migratory elk and non-migratory elk (t_{18} = -6.46, 95%). Differences were also detected in BYR 2OO6 in MCP home range estimates between migratory elk and non-migratory elk (t_{26} = -*3.17*, 95%). Additionally, differences were detected in BYR 2OO7 in MCP home range estimates between migratory elk and non-migratory elk (t_{30} = -4.64, 95%). Finally, differences were detected in BYR 2OO8 in MCP home range estimates between migratory elk and non-migratory elk (t_{28} = -3.167, 95%). Overall, the most compelling differences were detected in the aggregate MCP life home range estimates between migratory elk and non-migratory elk (t_{50} = -5.45, 95%). Differences may be viewed spatially in Figure 5, Figure 6, Figure 7, and Appendix 16.

Figure 5. GPS collared elk data points per migratory status in the Packwood subunit study area.



Migration

The data showed that approximately 66% of the herd was migratory, and 34% of the herd was non-migratory. The data also showed over the 4-year period of the study that the radio-collared elk demonstrated high range fidelity (99%). Study results showed 99% site fidelity of cow elk among summer ranges and winter ranges. This study showed not only range fidelity but considerable variation in migratory routes and summer range destinations.

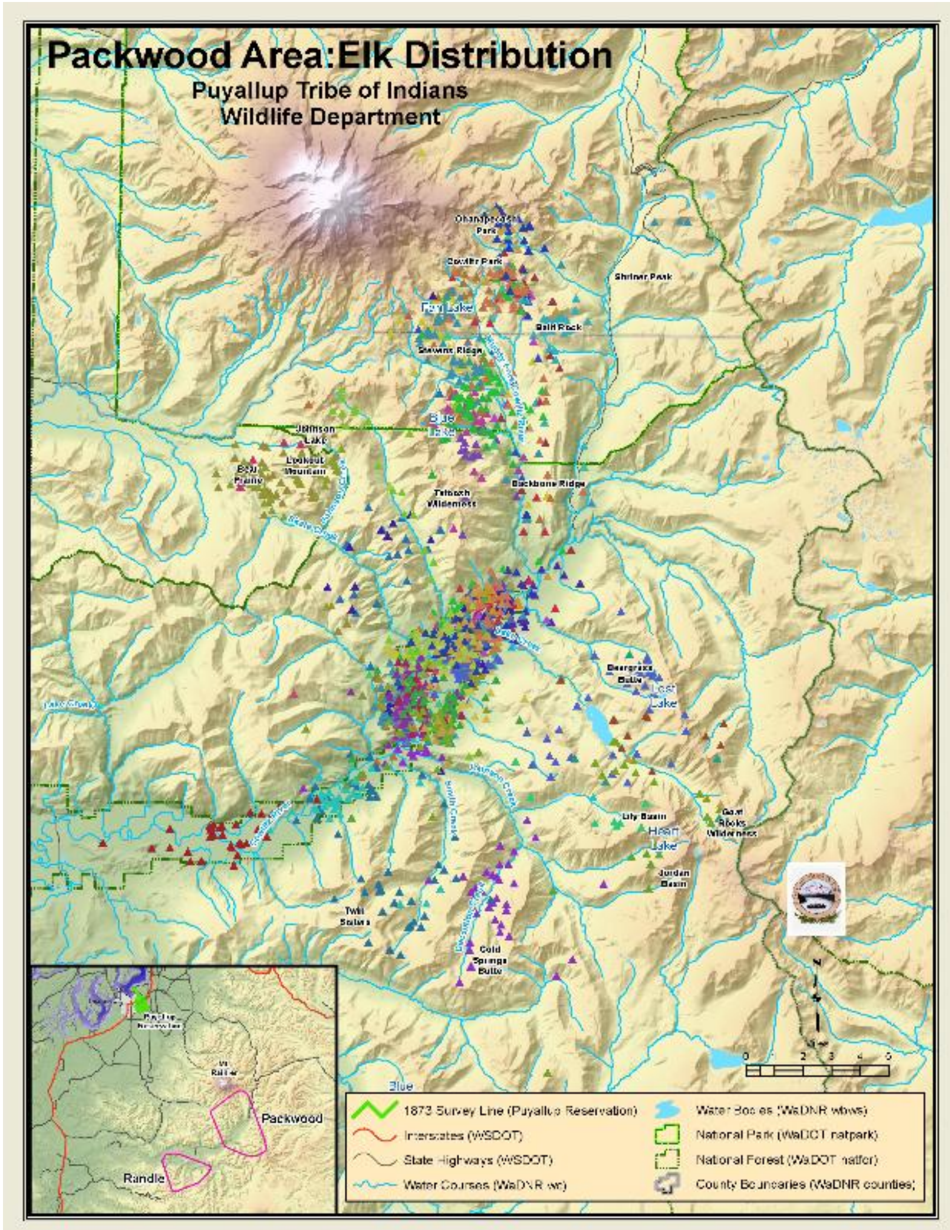
Distribution

Packwood Sub-Herd

The sub-herd wintering in the Packwood area, while showing high fidelity to seasonal range areas, the sub-herd as a whole showed quite a bit of variation in annual migration routes and summering destinations. An average of 20% of the Packwood sub-herd migrated annually to areas south of Packwood in the Gifford Pinchot National Forest, with destinations reaching into the Goat Rocks Wilderness Area. Routes and destinations included the following: Lake Creek/Snyder Ridge to Johnson Basin, Lake Creek/Snyder Ridge to Lily Basin, Lake Creek/Snyder Ridge to Lost Lake/Beargrass Butte, Johnson Creek to Heart Lake Basin, Johnson Creek to Jordan Basin, Johnson Creek/Deception Creek to Cold Springs Butte, and Smith Creek to Twin Sisters/Castle Butte (Figure 6).

An average of 46% of the sub-herd migrated to areas north of Packwood into Gifford Pinchot National Forest, the Tatoosh Wilderness Area, and Mount Rainier National Park (MRNP). Many of the elk that migrated to MRNP used similar migration routes into the Park even though their final destinations for summering varied. Routes and destinations included the following: Cowlitz Muddy Fork to Blue Lake area, Cowlitz Muddy Fork to Backbone Ridge area, Cowlitz Muddy Fork to Stevens Ridge area (MRNP), Cowlitz Muddy Fork to Fan Lake Area (MRNP), Cowlitz Muddy Fork to Cowlitz Park area (MRNP), Cowlitz Muddy Fork to Ohanapekosh Park area (MRNP), Cowlitz Muddy Fork to Bald Rock area (MRNP), Cowlitz Muddy Fork to Shriner Peak area, Butter Creek to Johnson Lake area (MRNP), and Skate Creek/Bear Prairie to Lookout Mountain area (Figure 6).

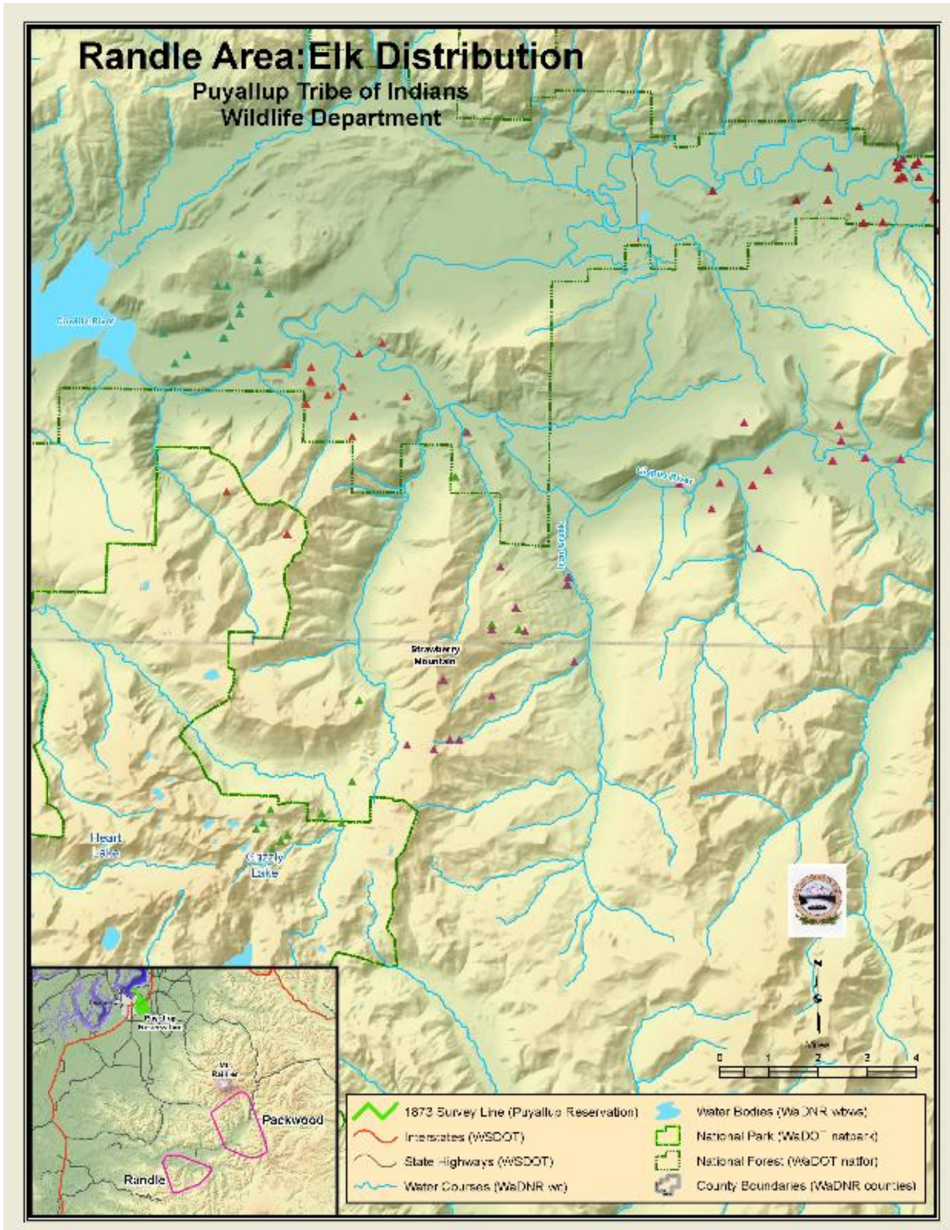
Figure 6. Elk distribution in the Packwood study area. Color coded triangles represent individual elk.



Randle Sub-Herd

Five elk were collared in the Randle area in years 2006 and 2008, one with a VHF radio-collar and the other four with GPS collars. Three of the five elk were non-migratory; one of the non-migratory elk was fitted with a VHF collar. The non-migratory VHF radio-collared elk that wintered in the Randle area along the Cowlitz River showed range fidelity year to year. Collared elk migrated up the Iron Creek drainage towards Mt. St. Helens to the Strawberry Mountain area and to the Boot and Grizzly Lake areas within the Mt. St. Helens National Monument area (Figure 7).

Figure 7. Elk distribution in the Randle study area. Color coded triangles represent individual elk.



Survival Rates

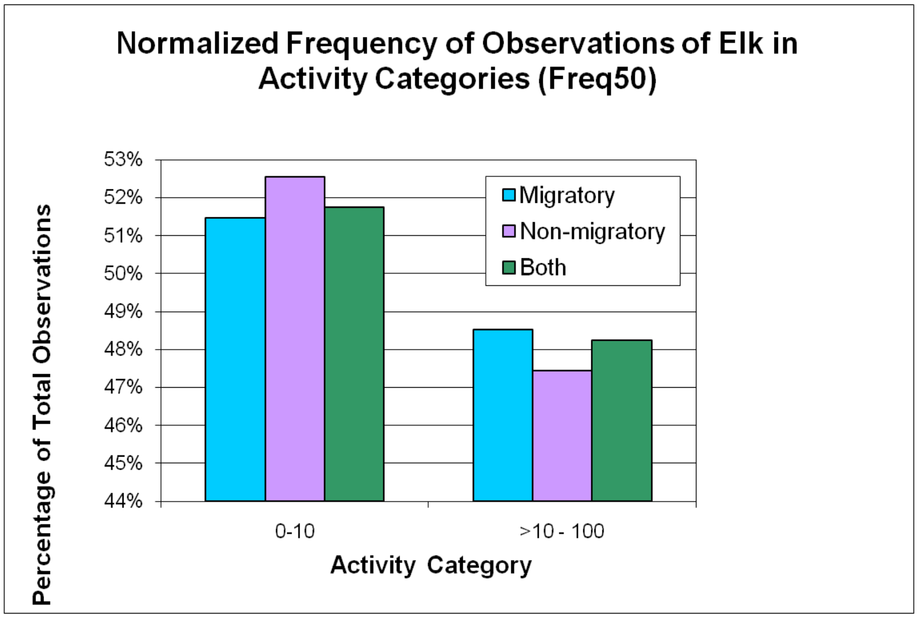
Known causes of mortality included legal harvest, auto collision, predator kills, starvation, and calving complications. Survival rates for 2004 using the bionomial estimator method were 74%, 2005 rates were 88%, and 2006 rates were 82%. In 2007 the survival rate using the Kaplen-Meier method was 71% and using the same method in 2008, the survival rate was 90%.

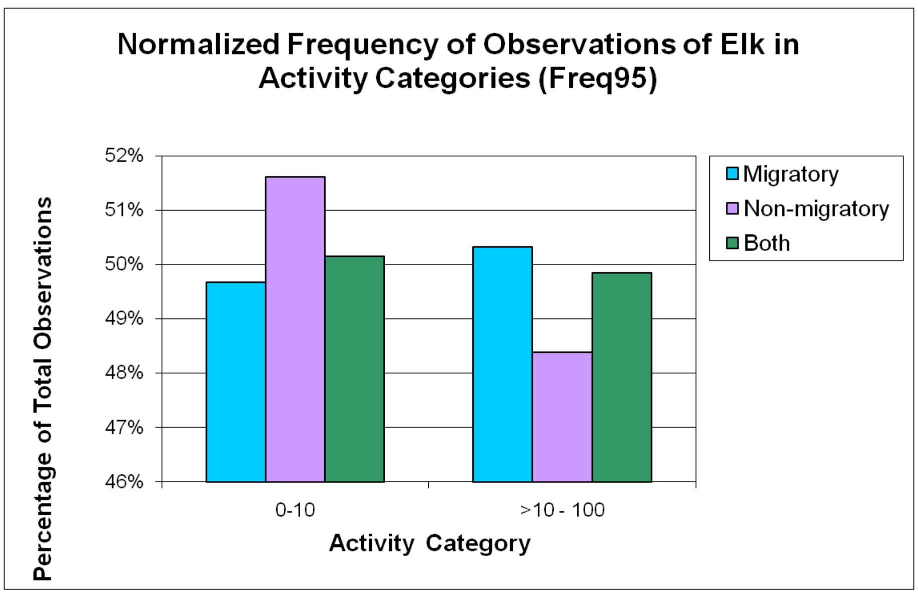
Habitat Use

Activity: 50% Range Analysis

Overall, migratory (M) elk were inactive/bedded 51.5% of the time, while non-migratory (NM) elk were inactive/bedded 53% of the time. The remainder of the time M elk were active/feeding 48.5% of the time, while the NM elk were active/feeding 47% of the time. Significant differences were detected between individual elk (which represented family/social groups of ~ 15 elk) and the migratory group as well as the overall study group of elk (Figure 8). Non-migratory elk #29 was less active than the other non-migratory elk (t_{13} = 0.039, p >.05) and more active than all of the elk in the study group (t_{13} = 0.09, p > 0.05). Similarly, M elk #30 was less active than both the migratory group (t_{13} = 0.018, p > .05) and the entire study group (t_{13} = 0.02, p > .05).

Figure 8. Activity categories represent number of collar movements per hour for elk in the combined Randle and Packwood study areas in the Southwest Cascades of Washington 2007-2008.





Activity 95% Range Analysis

Similar to the results for the 50% range analysis, non-migratoryNM elk were inactive/bedded slightly more of the time (52%) than their migratory counter-parts (50%). Differences were detected between two individual elk and their respective migratory group and the overall study group. Non-migratory elk #29 was less active than the other non-migratory elk (t_{13} = 0.011, p > .05) and also less active than all of the elk in the study group (t_{13} = 0.034, p > .05). Similarly, M elk #30 was less active than both the respective migratory group (t_{13} = 0.011, p > .05) and the entire study group (t_{13} = 0.028, p > .05).

Aspect 50% Range Analysis

Migratory elk spent 11% of their time in habitat that is considered flat, where NM elk spent 19% of their time in the flat habitat type. Annual breakdowns of percent use areas per migratory group may be viewed in Table 2. Migratory elk were found to use the SW aspect significantly less than the NM elk group (t_{13} = 0.035, p < .10). Seasonally, M and NM elk spent a greater percentage of their time in southern aspects during all four seasons. (Appendix 7).

Table 2. Overall annual habitat use of aspects by elk in the combined Randle and Packwood study areas at the 50% and 95% range scales in the Southwest Cascades of Washington. 2007-2008.

50% Contour Kernel Normalized			Aspect Category		
Individual	Flat (-1-0)	NE (0-90)	SE (90-180)	SW(180-270)	NW(270-360)
Migratory	11%	16%	32%	16%	25%
Non-migratory	19%	11%	24%	28%	18%
Both	13%	15%	30%	19%	23%

95% Contour Kernel Normalized			Aspect Category		
Individual	Flat (-1-0)	NE (0-90)	SE (90-180)	SW(180-270)	NW(270-360)
Migratory	8%	18%	31%	21%	23%
Non-migratory	15%	12%	24%	25%	23%
Both	9%	17%	29%	22%	23%

Several individual elk yielded differences in time spent in particular aspects than their respective migratory group and the entire study group of elk. Elk #28 was found to use the SW aspect less than the elk in its migratory group (t_{13} = 0.002, p < .10). Migratory Elk #28 was found to use the NW aspect more than the elk in its migratory group (t_{13} = 0.015, p > .05) and the overall study group of elk (t_{13} = 0.033, p > .05). Non-migratory Elk #29 used flat terrain more than elk in the entire study group (t_{13} = 0.036, p > .05). Non-migratory elk #81 used the flat aspect more than the elk in the entire study group (t_{13} = 0.016, p > .05). Migratory elk #84 used the NW aspect less than the elk in the entire study group (t_{13} = 0.075, p > .10). Non-migratory elk #419 spent more time in the SW aspect than the elk in its migratory group (t_{13} = 0.083, p > .10) as well as the entire study group of elk (t_{13} = 0.002, p > .05). Non-migratory elk #420 spent more time in the NE aspect than the elk in its migratory group (t_{13} = 0.012, p > .10; she also spent more time in the NW aspect than her migratory group (t_{13} = 0.012, p > .05). Migratory elk #421 used the SW aspect more than the elk in her migratory group (t_{13} = 0.090, p > .10). Migratory elk # 422 used the NE aspect less than the elk in the entire study group (t_{13} = 0.059, p > .10).

Aspect 95% Range Analysis

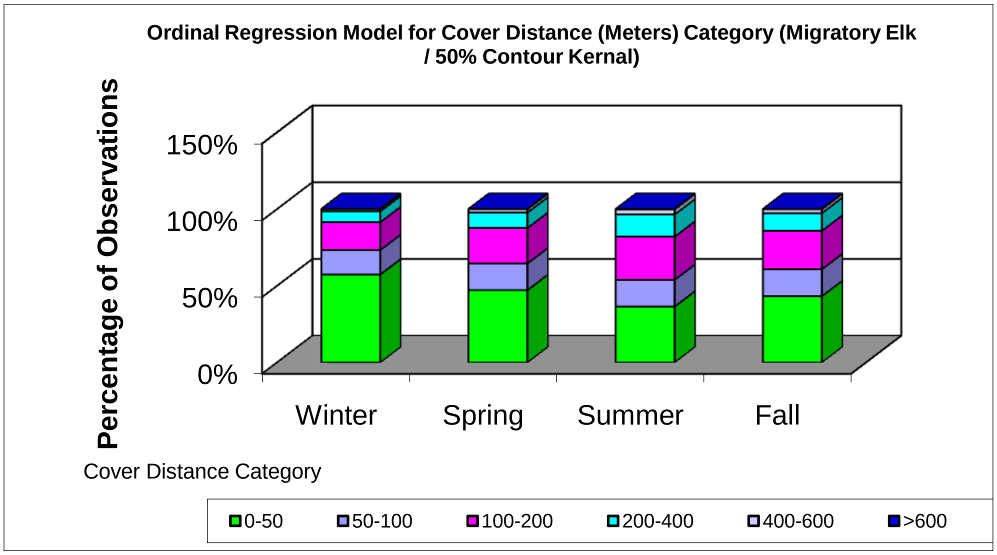
In the 95% range analysis, M elk spent 8% of their time in habitat that is considered flat, where NM elk spent 15% of their time in the flat habitat type. Annual breakdowns of percent use areas per migratory group may be viewed in Table 2. Seasonally, migratory and non-migratory elk spent a greater percentage of their time in southern aspects during all four seasons (Appendix 7).

Again, several individual elk yielded differences in time spent in particular aspects than their respective migratory group and the entire study group of elk. Migratory elk #28 was found to use the NW aspect more than the elk in her migratory group (t_{13} = 0.035, p > .05) and the overall study group of elk (t_{13} = 0.028, p > .05). Non-migratory elk #29 used flat terrain more than elk her entire study group (t_{13} = 0.065, p > .10). Non-migratory elk #81 used the flat aspect more than the elk in the entire study group (t_{13} = 0.002, p > .05). Non-migratory elk #85 used the SE aspect more than the elk in her migratory group (t_{13} = 0.063, p > .10) as well as the entire group of elk (t_{13} = 0.062, p > .10). Non-migratory elk #419 spent more time in the SW aspect than the elk in her migratory group (t_{13} = 0.066, p > .10) as well as the entire study group of elk (t_{13} = 0.001, p > .05). Non-migratory elk #420 spent more time in the NE aspect than the elk in her migratory group (t_{13} = 0.075, p > .10) as well as more time in the NW aspect than its migratory group (t_{13} = 0.023, p > .05). Migratory elk #421 used the NE aspect more than the elk the entire study group of elk (t_{13} = 0.076, p > .10). Migratory elk # 422 used the NE aspect less than the elk in the entire study group (t_{13} = 0.035, p > .05) as well as the elk within her migratory group (t_{13} = 0.094, p > .10).

Cover 50% Range Analysis

Significant differences between the migratory and non-migratory groups were observed in the 50-100 m distance category where NM elk were in this distance class more than M elk (t_{13} = 0.050, p > .05). Migratory elk spent 51% of their time within the 0-50 m distance class of cover where NM elk spent 35% of their time within the same distance class. Remaining distance class to cover comparisons generally also showed that NM elk spent more time in the lower distance classes (Table 3). During winter migratory elk spent 57% of their time within 50 m of cover as compared to non-migratory elk which spent 34% of their time within 50 m of cover (Figure 9 and Appendix 8).

Figure 9. Distance to cover analysis for migratory and non-migratory elk at the 50% scale in the Southwestern Cascades of Washington.



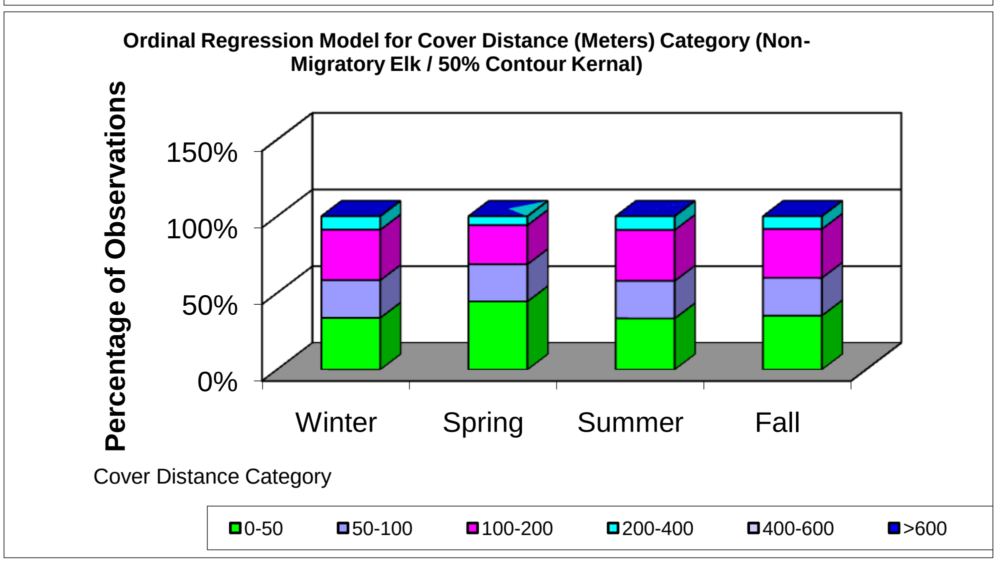


Table 3. Overall annual habitat use by elk relative to distance to cover in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

50% Contour Kernel	Distance from Cover (meters) Category					
Individual	0-50	50-100	100-200	200-400	400-600	>600
Migratory	51%	17%	21%	9%	2%	0%
Non-migratory	35%	25%	32%	8%	0%	0%
Both	47%	19%	24%	9%	1%	0%

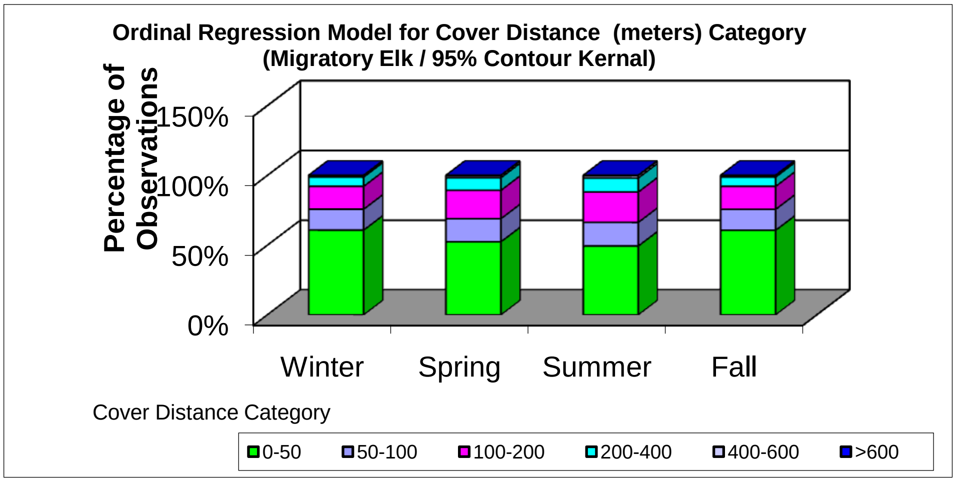
95% Contour Kernel	Distance from Cover (meters) Category					
Individual	0-50	50-100	100-200	200-400	400-600	>600
Migratory	56%	16%	18%	8%	1%	0%
Non-migratory	44%	22%	26%	8%	0%	0%
Both	53%	17%	20%	8%	1%	0%

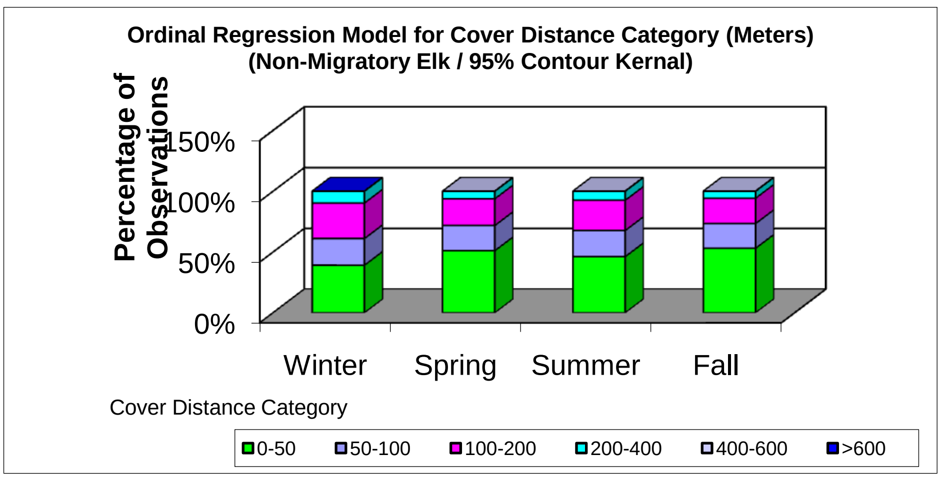
Several individual elk revealed significant differences with respect to distance class to cover with their respective migratory group as well as the entire study group of elk. Non-migratory elk #29 spent more time in the 100-200 m distance to cover category than the entire study group of elk (t_{13} = 0.087, p > .10). Migratory elk #30 spent more time in the 50-100 m distance category than her respective migratory group (t_{13} = 0.017, p > .05). Non-migratory elk #81 used the 50-100 m distance category more than the elk in the entire study group (t_{13} = 0.051, p > .10). Migratory elk #82 was found in the 0-50 m category more than elk in her respective migratory group (t_{13} = 0.031, p > .05) and the study group of elk as a whole (t_{13} = 0.046, p > .05). The same elk M #82 was found in the 100-200 m distance class less than elk in her migratory group (t_{13} = 0.008, p < .05) and entire study group of elk (t_{13} = 0.040, p < .05). Non-migratory elk #85 was found in the 0-50 m distance class more than her migratory group (t_{13} = 0.051, p > .10). The same elk, #85 was in the 50-100 m distance class (t_{13} = 0.079, p < .10) and the 100-200 m distance class (t_{13} = 0.079, p < .10) less than elk in her migratory group. Migratory elk #421 spent less time in the 0-50 m distance category than the other elk in her migratory group (t_{13} = 0.044, p < .05) However, M elk #421 spent significantly more time in the 200-400 m distance class than the elk in her migratory group (t_{13} = 0.002, p > .05) and the elk in the entire study group (t_{13} = 0.002, p > .05). The same elk (#421) was also found in the 400-600 m distance category more than the elk in her migratory group (t_{13} = 0.002, p > .05), and the elk in the entire study group (t_{13} = 0.002, p > .05).

Cover 95% Range Analysis

Significant differences between the migratory and non-migratory groups were observed in the 50-100 m distance category where migratory elk were in this distance class less than non-migratory elk (t_{13} = 0.017, p < .05). Migratory elk spent 56% of their time within the 0-50 m distance class of cover where NM elk spent 44% of their time within the same distance class. Remaining distance class to cover comparisons may be viewed in Table 3. Seasonally, during winter migratory elk spent 61% of their time within 50 m of cover as compared to non-migratory elk which spent 39% of their time within 50 m of cover (Figure 10 and Appendix 8).

Figure 10. Distance to cover analysis for migratory and non-migratory elk at the 95% scale in the Southwestern Cascades of Washington.





Several individual elk revealed significant differences with respect to distance class to cover and their respective migratory group as well as the entire study group of elk. Non-migratory elk #29 spent more time in the 100-200 m distance to cover category than the entire study group of elk (t_{13} = 0.041, p > .05). Migratory elk #30 spent more time in the 50-100 m distance to cover category more than her respective migratory group (t_{13} = 0.058, p > .10). Non-migratory elk #81 used the 0-50 m distance to cover category less than the elk in the entire study group (t_{13} = 0.050, p < .05). The same elk #81 used the 50-100 m distance to cover category more than her migratory group (t_{13} = 0.055, p > .10) and the entire study group of elk (t_{13} = 0.042, p > .05). Migratory elk #82 was found in the 0-50 m category more than elk in her respective migratory group (t_{13} = 0.072, p > .10) and the study group of elk as a whole (t_{13} = 0.072, p > .10). The same elk M #82 was found in the 100-200 m distance class less than the elk in her migratory group (t_{13} =

0.026, $p < .05$) and entire study group of elk ($t_{13} = 0.081$, $p > .10$). Non-migratory elk #85 was found in the 50-100 m distance class less than the entire study group of elk ($t_{13} = 0.092$, $p < .10$). Migratory elk #421 spent less time in the 0-50 m distance category than the other elk in her migratory group ($t_{13} = 0.049$, $p < .05$) However, M elk #421 spent more time in the 200-400 m distance class than the elk in her migratory group ($t_{13} = 0.001$, $p > .05$) and the elk in the entire study group ($t_{13} = 0.006$, $p > .05$). The same elk (421) was also found in the 400-600 m distance category more than the elk in her migratory group ($t_{13} = 0.000$, $p > .05$), and the elk in the entire study group ($t_{13} = 0.000$, $p > .05$).

Shrub/Scrub 50% Range Analysis

Migratory elk spent 65% of their time in the 0-50 m range of shrub/scrub while NM elk spent 58% of their time in the same distance class. Remaining distance class to shrub/scrub comparisons may be viewed in Table 4. Seasonal break downs by percentage of data points in each distance class may be viewed in Appendix 9.

Table 4. Overall annual habitat use by elk relative to distance to shrub/scrub in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

50% Contour Kernel			Distance (Meters) from Shrub/Scrub Category			
Individual	0-50	50-100	100-200	200-400	400-600	>600
Migratory	65%	10%	14%	8%	2%	1%
Non-migratory	58%	11%	17%	14%	1%	0%
Both	63%	10%	15%	10%	1%	1%

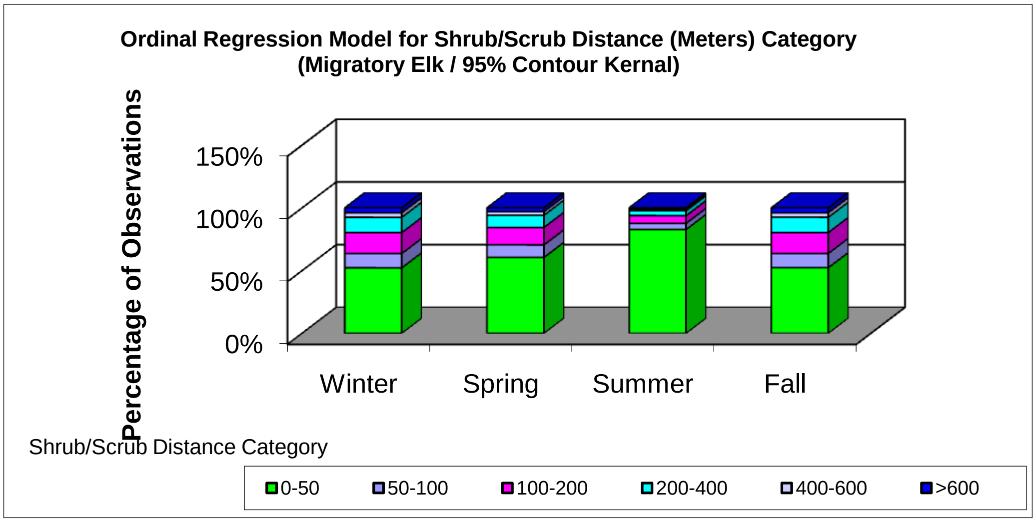
95% Contour Kernel Normalized			Distance (Meters) from Shrub/Scrub Category			
Individual	0-50	50-100	100-200	200-400	400-600	>600
Migratory	62%	9%	14%	10%	3%	3%
Non-migratory	55%	12%	19%	13%	1%	0%
Both	60%	10%	15%	10%	2%	2%

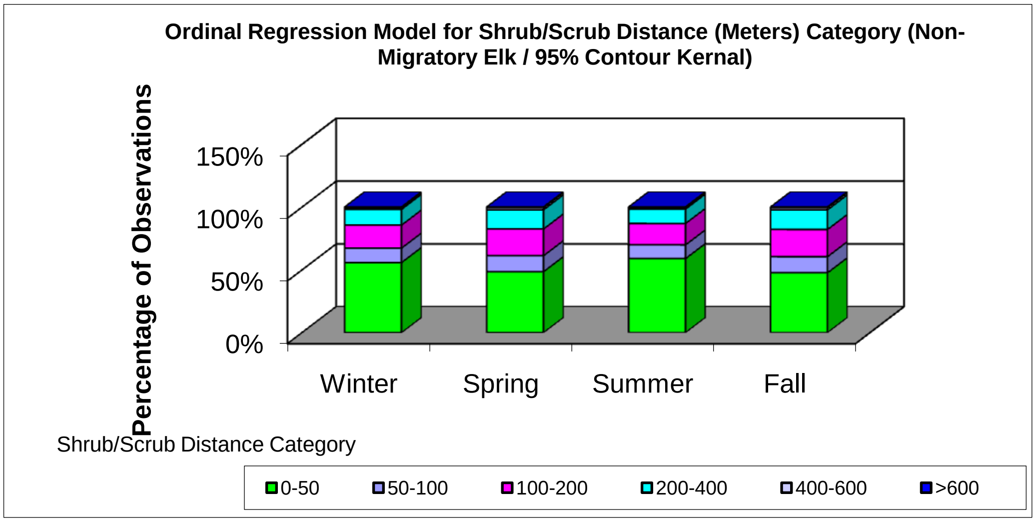
Many individual elk showed significant differences between distance to shrub/scrub habitat in comparison to their migratory group and the entire study group of elk. Migratory elk #80 spent more time in the 400-600 m distance from shrub/scrub than the elk in her migratory group (t_{13} = 0.000, p > .05) and the entire study group of elk (t_{13} = 0.000, p > .05). Non-migratory elk # 81 spent less time in the 0-50 m distance class to shrub/scrub than the elk in the entire study group (t_{13} = 0.064, p > .10). The same elk #81 spent more time in both the 50-100 m (t_{13} = 0.018, p > .05) and 100-200 m distance classes than the elk in the entire study group (t_{13} = 0.062, p > .10). Migratory elk #83 spent more time in the >600 m distance class to shrub/scrub than the elk in her migratory group (t_{13} = 0.000, p > .05) and the entire study group of elk (t_{13} = 0.000, p > .05). Non-migratory elk #84 spent less time in the 0-50 m distance class from shrub/scrub than the migratory elk in her group (t_{13} = 0.063, p > .10). The same elk #84 spent more time in the 100-200 m distance category to shrub/scrub than the elk in her migratory group (t_{13} = 0.008, p > .05) and the elk in the entire study group of elk (t_{13} = 0.043, p > .05). Non-migratory elk #420 spent more time in the 200-400 m distance to shrub/scrub category than the entire study group of elk (t_{13} = 0.040, p > .05).

Shrub/Scrub 95% Range Analysis

Some differences were detected between the two groups of elk where M elk were found to be in the > 600 m distance class from shrub/scrub more than NM elk (t_{13} = 0.056, p > .10). Migratory elk spent 62% of their time in the 0-50 m range of shrub/scrub while NM elk spent 55% of their time in the same distance class. Remaining distance class to shrub/scrub comparisons may be viewed in Table 4. Seasonal break downs by percentage of data points in each distance class may be viewed in Figure 11 and Appendix 9.

Figure 11. Distance to shrub/scrub analysis for migratory and non-migratory elk in the Southwestern Cascades of Washington.





Many individual elk showed significant differences between distance classes to shrub/scrub habitat in comparison to their migratory group and the entire study group of elk. Migratory elk #30 spent less time in the 200-400 m distance class than the elk in her migratory group (t_{13} = 0.086, p < .10). Migratory elk #80 spent more time in the 400-600 m distance from shrub/scrub than the elk in her migratory group (t_{13} = 0.010, p > .05) and the entire study group of elk (t_{13} = 0.004, p > .05). Non-migratory elk # 81 spent less time in the 0-50 m distance class to shrub/scrub than the elk in the entire study group (t_{13} = 0.053, p < .10). The same elk #81 spent more time in both the 50-100 m distance class (t_{13} = 0.009, p > .05) and 100-200 m distance classes than the elk in the entire study group (t_{13} = 0.033, p > .05). Non-migratory elk #84 spent less time in the 0-50 m distance class from shrub/scrub than the entire group of elk in the study (t_{13} = 0.051, p < .10). The same elk #84 spent more time in the 100-200 m distance category to shrub/scrub than the elk in her migratory group (t_{13} = 0.011, p > .05) and the elk in the entire study group (t_{13} = 0.091, p > .10). Non-migratory elk #419 spent more time in the >600 m distance category than the elk in the entire study group (t_{13} = 0.008, p > .05). Non-migratory elk #420 spent less time in the 0-50 m distance category than all of the elk in the entire study group (t_{13} = 0.093, p > .10). The same elk #420 spent more time in the 200-400 m distance to shrub/scrub category than the entire study group of elk (t_{13} = 0.031, p > .05). Elk # 420 also spent more time in the 400-600 m distance category than the elk in her migratory group (t_{13} = 0.000, p > .05). Migratory elk #421 spent less time in the 50-100 m distance category than the elk in her migratory group (t_{13} = 0.088, p < .10). Migratory elk #422 spent more time in the 400-600 m distance class than both the migratory group (t_{13} = 0.019, p > .05) and the entire study group of elk (t_{13} = 0.002, p > .05).

Slope 50% Range Analysis

Significant differences were detected between the migratory and non-migratory groups of elk with regard to slope preferences. The differences that were detected between the two groups were where the migratory elk utilized 1-15% slope areas less than the migratory elk (t_{13} = 0.089, p < .10). Also, migratory elk preferred steeper 15-30% slopes (t_{13} = 0.082, p > .10) and >45% slopes more than non-migratory elk (t_{13} = 0.053, p > .10). Overall, migratory elk spent 10% of their time within the 0-1% slope class where NM elk spent 18% of their time within the same slope class. Remaining slope class comparisons may be viewed in Table 5. Seasonally, migratory elk also spent a greater percentage of their time on steeper slopes comparatively than non-migratory elk (Figure 12-13 and Appendix 10).

Table 5. Annual overall habitat use by elk of slopes in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

50% Contour Kernel Normalized		Percent Slope Category			
Individual	0-1	1-15	15-30	30-45	45-25000
Migratory	10%	47%	20%	12%	11%
Non-migratory	18%	61%	10%	7%	3%
Both	12%	51%	18%	11%	9%

95% Contour Kernel Normalized		Percent Slope Category			
Individual	0-1	1-15	15-30	30-45	45-25000
Migratory	7%	40%	22%	16%	16%
Non-migratory	14%	62%	14%	7%	3%
Both	9%	45%	20%	13%	13%

Several individual elk yielded significant differences in their preferences of particular slope classes than their respective migratory group and the entire study group of elk. Migratory elk #28 preferred 15-30% slope areas more than the entire study group of elk (t_{13} = 0.023, p > .05) and more than the elk in her migratory elk group (t_{13} = 0.058, p > .10). Non-migratory elk #29 preferred flat sloped areas of 0-1% grades more than the elk in the entire study group (t_{13} = 0.033, p > .05). Non-migratory elk #81 also preferred flat sloped areas of 0-1% grades more than the rest of the elk in the entire study group (t_{13} = 0.014, p > .05). Non-migratory elk #85 preferred 1-15% slopes more than the entire study group of elk (t_{13} = 0.063, p > .10). Whereas NM Elk #419 preferred 30-45% slopes (t_{13} = 0.014, p > .05) and >45% slopes more than the elk in her non-migratory group (t_{13} = 0.028, p > .05). Migratory elk #421 showed less preference for 1-15% slope areas than all of the elk in the study group (t_{13} = 0.079, p < .10). The same elk (#421) showed greater preference for slope areas >45% than the elk in both her migratory group (t_{13} = 0.033, p > .05) and the entire study group of elk (t_{13} = 0.006, p > .05). Migratory elk #422 was less likely to be found using areas with 1-15% slope than the elk in the entire study group (t_{13} = 0.084, p < .10). The same elk (#422) was found to prefer 30-45%

slopes more than elk in her migratory group (t_{13} = 0.008, p > .05) and the entire study group of elk (t_{13} = 0.009, p > .05).

Slope 95% Range Analysis

More pronounced differences were detected between the migratory and non-migratory groups of elk with regard to slope preferences at the 95% range areas. Highly significant differences were detected between the two groups where migratory elk utilized 1-15% slope areas less than migratory elk (t_{13} = 0.004, p < .05). As well, highly significant differences were detected where migratory elk preferred steeper 15-30% slopes (t_{13} = 0.047, p > .05), 30-45% slopes (t_{13} = 0.008, p > .05) and >45% slopes more than non-migratory elk (t_{13} = 0.000, p > .05). Overall, migratory elk spent 7% of their time within the 0-1% slope class where NM elk spent 14% of their time within the same slope class. Remaining slope class comparisons may be viewed in Table 5. Seasonally, migratory elk also spent a greater percentage of their time on steeper slopes comparatively than non-migratory elk (Figure 12-13 and Appendix 10).

Figure 12: Migratory elk habitat selection with slope analysis.

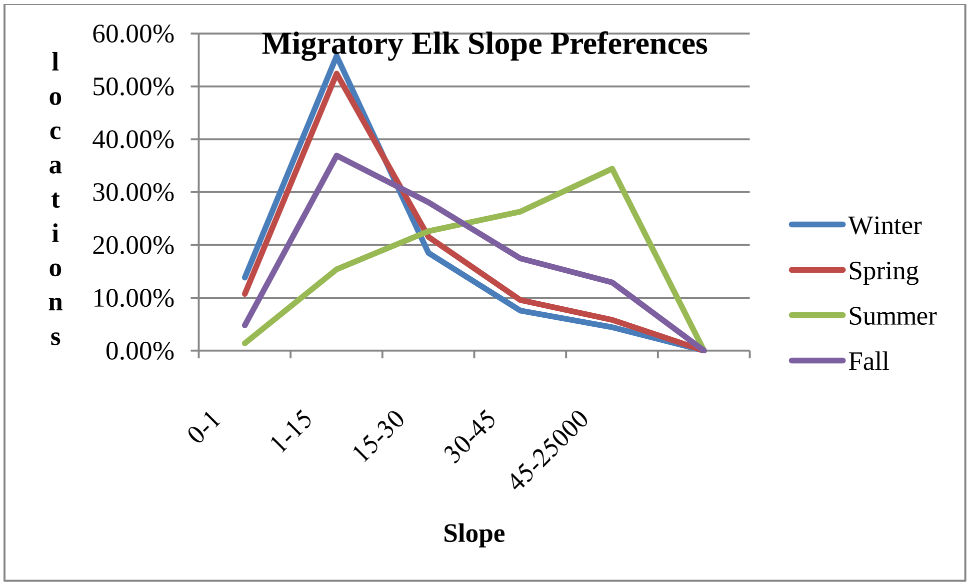
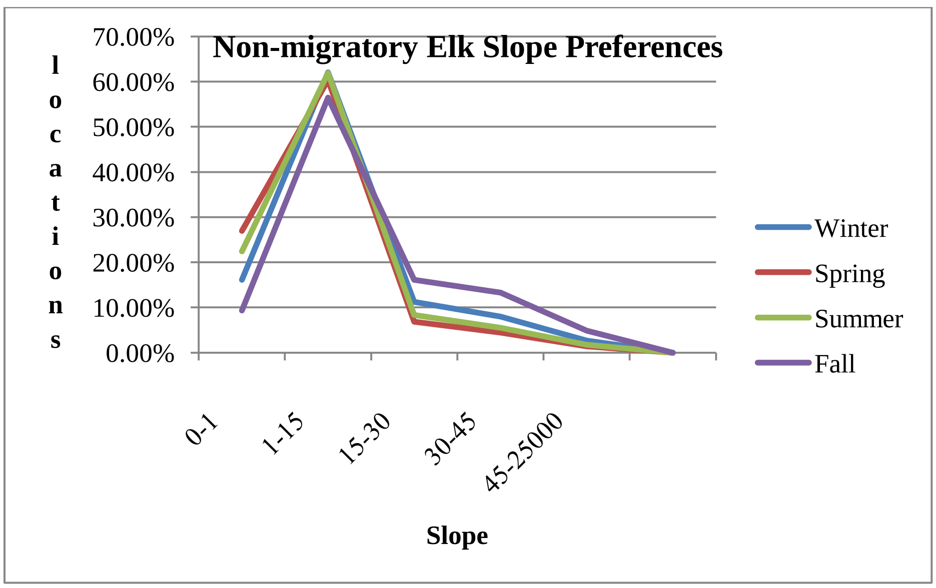


Figure 13. Non-migratory elk habitat selection with slope analysis.



Several individual elk yielded differences in preferences of particular slope classes than their respective migratory group and the entire study group of elk. Non-migratory elk #29 preferred flat sloped areas of 0-1% grades more than the elk in the entire study group (t_{13} = 0.061, p > .10). Migratory elk #30 showed a preference to flat 0-1% sloped areas than the other elk in her respective migratory group (t_{13} = 0.087, p > .10). Non-migratory elk #81 also preferred flat sloped areas of 0-1% grades more than the rest of the elk in the entire study group (t_{13} = 0.002, p > .05). The same elk (#81) showed less preference for 1-15% slope areas than elk in her migratory group (t_{13} = 0.053, p < .10) and the entire study group of elk (t_{13} = 0.035, p < .05). Migratory elk #82 showed a greater preference for 1-15% slope areas than the elk in her respective migratory group (t_{13} = 0.078, p >.10). Non-migratory elk #85 preferred 1-15% slopes more than the entire study group of elk (t_{13} = 0.043, p > .05). Whereas Non-migratory elk #419 preferred 30-45% slopes (t_{13} = 0.020, p > .05) and >45% slopes more than the elk in her non-migratory group (t_{13} = 0.045, p > .05). Migratory elk #421 showed greater preference for slope areas >45% than the elk in both her migratory group (t_{13} = 0.031, p > .05) and the entire study group of elk (t_{13} = 0.022, p > .05). Migratory elk #422 was less likely to be found using areas with 1-15% slope than the elk in the entire study group (t_{13} = 0.082, p < .10). The same elk (#422) was found to prefer 30-45% slopes more than elk in her migratory group (t_{13} = 0.001, p > .05) and the entire study group of elk (t_{13} = 0.008, p > .05).

Water 50% Range Analysis

Migratory elk spent 12% of their time in the 0-50 m range of water while NM elk spent 11% of their time in the same distance class. Remaining distance class to water comparisons may be viewed in Table 6. Seasonally, migratory elk generally were not found in distances greater than 600 m to water (8%) whereas non-migratory elk spent greater percentages of time at distances greater than 600 m on average 28% of the time (Appendix 11). On average, migratory elk spent 8% of their time at distances greater than 600 m from water.

Table 6. Overall annual habitat use by elk relative to distance to water in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

50% Contour Kernel Normalized	Distance (Meters)from Water Category					
Individual	0-50	50-100	100-200	200-400	400-600	>600
Migratory	12%	11%	22%	27%	16%	12%
Non-migratory	11%	9%	18%	25%	12%	26%
Both	12%	11%	21%	26%	15%	15%

95% Contour Kernel Normalized	Distance (Meters) from Water Category					
Individual	0-50	50-100	100-200	200-400	400-600	>600
Migratory	11%	10%	20%	26%	16%	17%
Non-migratory	12%	10%	18%	23%	13%	25%
Both	11%	10%	20%	25%	15%	19%

Many individual elk showed significant differences between distance classes to water habitat in comparison to their migratory group and the entire study group of elk. Non-migratory elk #29 showed a preference for spending more time in the 200-400 m distance class to water than all of the elk in the entire study group (t_{13} = 0.048, p > .05). The same elk (#29) spent more time in the 400-600 m distance category than other elk in her respective migratory group (t_{13} = 0.093, p > .10). Migratory elk #30 spent more time in the 0-50 m distance category than both her migratory group (t_{13} = 0.032, p > .05) and the entire study group of elk (t_{13} = 0.050, p > .10). The same elk (#30) also spent more time in the 50-100 m distance category than both her migratory group (t_{13} = 0.060, p > .10) and the entire study group of elk (t_{13} = 0.051, p > .10). Migratory elk #31 spent less time in the 100-200 m distance category than the other elk in her migratory group (t_{13} = 0.041, p < .05). The same elk (#31) also spent more time in the 400-600 m distance category than both her migratory group (t_{13} = 0.045, p > .05) and the entire study group of elk (t_{13} = 0.033, p > .05). Elk #31 also spent more time in the >600 m distance category than the other elk in her migratory group (t_{13} = 0.033, p > .05). Non-migratory elk #80 spent more time in the 200-400 m distance category than the other elk in her migratory group (t_{13} = 0.086, p > .10). Migratory elk #83 spent less time in the 200-400 m category than the elk in her migratory group (t_{13} = 0.096, p < .10). Non-migratory elk #419 spent more time in the >600 m category than both her respective migratory group (t_{13} = 0.000, p > .05) and the elk in the entire study group (t_{13} = 0.000, p > .05). Non-migratory elk #420 spent more time in the 0-50 m distance category than both the elk in her migratory group (t_{13} = 0.017, p > .05) and the entire study group of elk (t_{13} = 0.039, p > .05). The same elk (#420) also spent more time in the 50-100 m distance category than the other elk in her migratory group (t_{13} = 0.092, p > .10). Finally, M Elk #422 spent more time in the 400-600 m distance category than all of the elk in the entire study group (t_{13} = 0.079, p > .10).

Water 95% Range Analysis

Migratory elk spent 11% of their time in the 0-50 m range of water while NM elk spent 12% of their time in the same distance class. Remaining distance class to water comparisons may be viewed in Table 6. Seasonally, migratory elk generally were not found in distances greater than 600 m from water whereas non-migratory elk spent approximately 25% of their time at distances greater than 600 m (Appendix 11).

Many individual elk showed significant differences between distance classes to water habitat in comparison to their migratory group and the entire study group of elk. Migratory elk #30 spent more time in the 0-50 m distance category than her migratory group (t_{13} = 0.061, p > .10). The same elk (#30) also spent more time in the 50-100 m distance category than the elk in her migratory group (t_{13} = 0.096, p > .10). Migratory elk #31 spent less time in the 100-200 m distance category than the other elk in her migratory group (t_{13} = 0.036, p < .05). The same elk (#31) also spent more time in the 400-600 m distance category than both her migratory group (t_{13} = 0.042, p > .05) and the entire study group of elk (t_{13} = 0.021, p > .05). Elk #31 also spent more time in the >600 m distance category than the other elk in her migratory group (t_{13} = 0.053, p > .10). Non-migratory elk #85 spent more time in the 100-200 m distance class than other elk in her migratory group (t_{13} = 0.006, p > .05). Non-migratory elk # 419 spent less time in the 50-100 m distance category than all of the elk in the entire study group (t_{13} = 0.086, p < .10). The same elk spent less time in the 100-200 m category than all of the elk in the study group (t_{13} = 0.083, p < .10). Elk #419 also spent less time in the 200-400 m category than all of the elk in the study group (t_{13} = 0.032, p < .05). In addition, NM Elk #419 spent more time in the >600 m category than both her respective migratory group (t_{13} = 0.001, p > .05) and the elk in the entire study group (t_{13} = 0.000, p > .05). Non-migratory elk #420 spent more time in the 0-50 m distance category than both the elk in her migratory group (t_{13} = 0.051, p > .10) and the entire study group of elk (t_{13} = 0.024, p > .05). The same elk (#420) also spent more time in the 50-100 m distance category than all of the elk in the entire study group (t_{13} = 0.096, p > .10). Finally, M Elk #422 spent more time in the 400-600 m distance category than all of the elk in the entire study group (t_{13} = 0.065, p > .10).

Distance to Paved Roads 50% Range Areas

Overall, migratory elk were found to be within 600 m of paved roads 54% of the time whereas non-migratory elk were in the same distance class 64% of the time. The opposite was true for time spent in the >600 m of paved roads where migratory elk spent 47% of their time in the distance class and non-migratory spent 37% of their time in the >600 m distance class (Table 7). Seasonal break downs by percentage of data points in each distance class may be viewed in Appendix 12.

Table 7. Overall annual habitat use by elk relative to distance to paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

50% Contour Kernel Normalized		Distance (Meters)from Paved Road Category
Individual	0-600	>600
Migratory	54%	46%
Non-migratory	64%	36%
Both	56%	44%

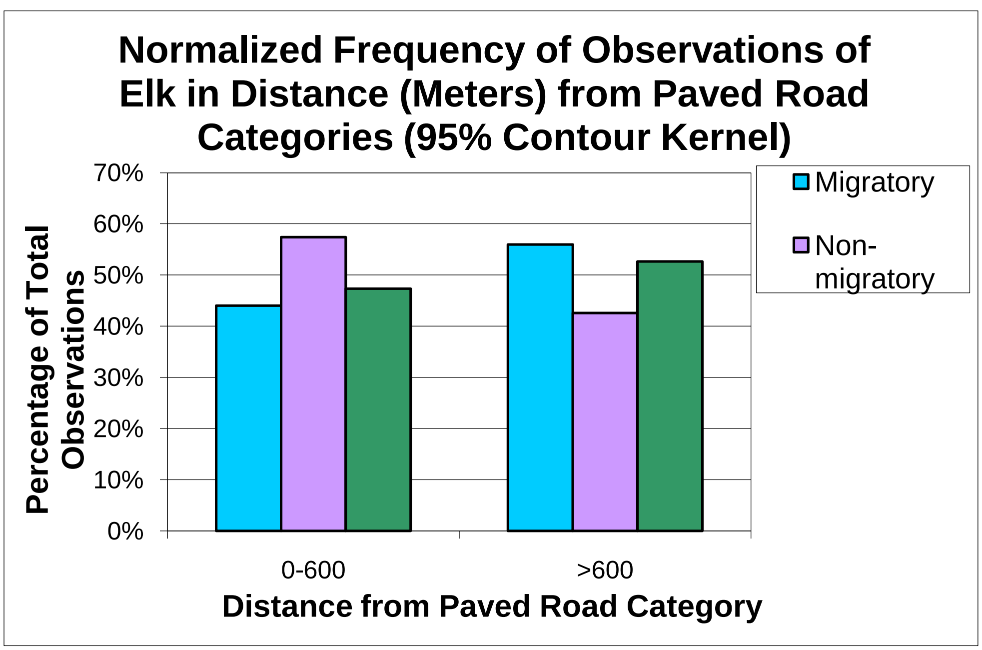
95% Contour Kernel Normalized		Distance (Meters)from Paved Road Category
Individual	0-600	>600
Migratory	44%	56%
Non-migratory	57%	43%
Both	47%	53%

Individual elk did show some significant differences between preferences in distance classes to paved roads in comparison to their respective migratory group and the entire study group of elk. Migratory elk #31 spent less time within 60 m of paved roads than the entire group of elk in the study ($t_{13} = 0.063$, $p < .10$). The same elk (#31) spent more time >600 m from paved roads than the elk in the study group ($t_{13} = 0.063$, $p > .10$). Similarly, NM Elk #419 spent less time within 600 m of paved roads than the other elk in her migratory group ($t_{13} = 0.086$, $p < .10$) The same elk (#419) spent less time in the >600 m from paved roads distance class than the elk in her migratory group ($t_{13} = 0.086$, $p > .10$).

Distance to Paved Roads 95% Range Areas

Overall, migratory elk were found to be within 600 m of paved roads 44% of the time whereas non-migratory elk were in the same distance class 57% of the time. The opposite was true for time spent in the >600 m of paved roads where migratory elk spent 56% of their time in the distance class and non-migratory spent 43% of their time in the >600 m distance class (Table 7). Seasonal break downs by percentage of data points in each distance class may be viewed in Figure 14 and Appendix 12.

Figure 14: Migratory and Non-migratory elk habitat use and distance to roads in the Southwestern Cascades of Washington.



Individual elk did show significant differences between distance classes to paved roads in comparison to their respective migratory group and the entire study group of elk. Migratory elk #31 spent less time within 600 m of paved roads than the entire group of elk in the study group (t_{13} = 0.075, p < .10). The same elk (#31) spent more time >600 m from paved roads than the elk in the study group (t_{13} = 0.075, p > .10). Similarly, NM Elk #420 spent less time within 600 m of paved roads than the other elk in the entire study group (t_{13} = 0.055, p < .10) The same elk (#420) spent more time >600 m from paved roads than the elk in her migratory group (t_{13} = 0.055, p > .10).

Distance to Non-Paved Roads 50% Range Areas

Overall, migratory elk were found within 100 m of non-paved roads 7% of the time where non-migratory elk were in the same distance class 3% of the time. Remaining distance class to non-paved roads comparisons may be viewed in Table 8. Seasonal break downs by percentage of data points in each distance class may be viewed in Appendix 13.

Table 8. Overall annual habitat use by elk relative to distance to non-paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the SW Cascades of Washington, 2007-2008.

50% Contour Kernel Normalized			Distance (Meters)from Non-Paved Road Category		
Individual	0-100	100-200	200-400	400-600	>600
Migratory	7%	7%	15%	19%	53%
Non-migratory	3%	9%	25%	15%	47%
Both	6%	7%	17%	18%	51%

95% Contour Kernel Normalized			Distance (Meters)from Non-Paved Road Category		
Individual	0-100	100-200	200-400	400-600	>600
Migratory	8%	8%	14%	15%	55%
Non-migratory	6%	9%	23%	15%	48%
Both	8%	8%	16%	15%	53%

Individual elk did show significant differences between distance classes to non-paved roads in comparison to their respective migratory group and the entire study group of elk. Migratory elk #28 spent more time within 100 m of non-paved roads than elk within her respective migratory group (t_{13} = 0.000, p > .05) and the entire study group of elk (t_{13} = 0.000, p > .05). The same elk (#28) was also found to be within the 100-200 m distance class of non-paved roads more than the elk in her migratory group (t_{13} = 0.004, p > .05) and the entire study group of elk (t_{13} = 0.017, p > .05). Elk #28 also was found in the >600 m distance class less than the elk in her migratory group (t_{13} = 0.094, p > .10). Migratory elk #30 was found in the 400-600 m distance class more than the elk in her migratory group (t_{13} = 0.047, p > .05) and the entire study group of elk (t_{13} = 0.048, p > .05). Migratory elk #83 was found in the 200-400 m distance class less than the elk in her migratory group (t_{13}= 0.099, p < .10). Non-migratory elk #84 was also found in the 200-400 m distance class less than the elk in her migratory group (t_{13} = 0.099, p < .10). The same elk (#84) was also in the >600 m distance class less than the other elk in her migratory group (t_{13} = 0.095, p < .10. Finally, NM elk #420 showed differences where she was within 100 m of non-paved roads more than the elk in her migratory group (t_{13} = 0.001, p > .05). The same elk (#420) spent more time in the 100-200 m distance class than the elk in her migratory group (t_{13} = 0.027, p > .05) and the elk in the entire study group (t_{13} = 0.029, p > .05). Elk #420 also spent more time in the 200-400 m distance class than the elk in her migratory group (t_{13} = 0.005, p > .05) and the elk in the entire study group (t_{13} = 0.085, p > .10).

Distance to Non-Paved Roads 95% Range Areas

Overall, migratory elk were found within 100 m of non-paved roads 8% of the time where non-migratory elk were in the same distance class 6% of the time. Remaining distance class to non-paved roads comparisons may be viewed in Table 8. Seasonal break downs by percentage of data points in each distance class may be viewed in Appendix 13.

Individual elk did show significant differences between distance classes to non-paved roads in comparison to their respective migratory group and the entire study group of elk. Migratory elk #28 spent more time within 100 m of non-paved roads than elk in her respective migratory group (t_{13} = 0.010, p > .05) and the entire study group of elk (t_{13} = 0.011, p > .05). The same elk (#28) was also found to be within the 100-200 m distance class of non-paved roads more than the elk in her migratory group (t_{13} = 0.046, p > .05). Migratory elk #30 was found in the 400-600 m distance class more than the elk in her migratory group (t_{13} = 0.014, p > .05) and the entire study group of elk (t_{13} = 0.047, p > .05). Non-migratory elk #81 was found in the 400-600 m distance class more than the elk in the entire study group (t_{13} = 0.082, p > .10). Migratory elk #83 was found in the >600 m distance class more than the elk in her migratory group (t_{13} = 0.058, p > .10). Non-migratory elk #84 was found in the 200-400 m distance class less than the elk in her migratory group (t_{13} = 0.027, p < .05). The same elk (#84) was in the >600 m distance class more than the other elk in her migratory group (t_{13} = 0.088, p > .10). Non-migratory elk #85 was in the >600 m distance class more than all of the elk in the study group (t_{13} = 0.062, p > .10). Finally, NM elk #420 showed differences where she was within 100 m of non-paved roads more than the elk in her migratory group (t_{13} = 0.000, p > .05). The same elk (#420) spent more time in the 100-200 m distance class than the elk in her migratory group (t_{13} = 0.012, p > .05) and the elk in the entire study group (t_{13} = 0.006, p > .05). Elk #420 also spent more time in the 200-400 m distance class than the elk in her migratory group (t_{13} = 0.060, p > .10) and the elk in the entire study group (t_{13} = 0.000, p > .05). In addition, elk #420 was found in the >600 m of non-paved roads less than the elk in the entire study group (t_{13} = 0.021, p > .05).

Distance to Trails 50% Range Areas

Overall, migratory elk spent 1% of their time within 100 m of trails, where non-migratory elk spent 0% of their time in the same distance class. Remaining distance class to trails comparisons may be viewed in Table 9. Seasonal break downs by percentage of data points in each distance class may be viewed in Appendix 14.

Table 9. Overall annual habitat use by elk relative to distance to trails in the combined Randle and Packwood study areas at the 50% and 95% range scale in the SW Cascades of Washington, 2007-2008.

50% Contour Kernel Normalized			Distance (Meters) from Trail Category		
Individual	0-100	100-200	200-400	400-600	>600
Migratory	1%	1%	2%	2%	94%
Non-migratory	0%	0%	0%	0%	100%
Both	1%	1%	2%	2%	95%

95% Contour Kernel Normalized			Distance (Meters) from Trail Category		
Individual	0-100	100-200	200-400	400-600	>600
Migratory	2%	2%	4%	3%	89%
Non-migratory	0%	0%	1%	1%	98%
Both	2%	1%	3%	3%	91%

Individual elk did show significant differences between distance classes to trails in comparison to their respective migratory group and the entire study group of elk. Migratory elk #421 was found in the 100-200 m distance class more than the elk in the entire study group (t_{13} = 0.053, p > .10). The same elk (#421) was found in the 400-600 m distance class more than the elk in her migratory group (t_{13} = 0.031, p > .05) and the entire study group of elk (t_{13} = 0.004, p > .05). Elk #421 was less likely to be found in the >600 m distance class than the elk in the entire study group (t_{13} = 0.078, p < .10). Migratory elk #422 was found within 100 m of trails more than both the elk in her migratory group (t_{13} = 0.000, p > .05) and the entire study group of elk (t_{13} = 0.000, p > .05). The same elk (#422) was found in the 100-200 m distance class (t_{13} = 0.004, p > .05), 200-400 m distance class (t_{13} = 0.000, p > .05), 400-600 m distance class (t_{13} = 0.047, p > .05) and the >600 m distance class (t_{13} = 0.002, p > .05) more than the elk in her migratory group. In addition, elk #422 was also found in the following distance categories more than the elk in the entire study group of elk: 100-200 m distance class (t_{13} = 0.000, p > .05), 200-400 m distance class (t_{13} = 0.000, p > .05), 400-600 m distance class (t_{13} = 0.008, p > .05) and the >600 m distance class (t_{13} = 0.000, p > .05).

Distance to Trails 95% Range Areas

Significant differences were detected between the migratory and non-migratory groups of elk in relation to habitat used near trails. Differences were detected between the two groups where migratory elk were found within 100 m more often than their non-migratory counterparts (t_{13} = 0.033, p > .05). Migratory elk were also found more often within the following distance categories than non-migratory elk: 100-200 m distance class (t_{13} = 0.055, p > .10), 200-400 m (t_{13} = 0.049, p > .05), 400-600 m (t_{13} = 0.041, p > .05). However, migratory elk were found in the >600 m distance class less often than non-migratory elk (t_{13} = 0.041, p < .05). Overall, migratory elk spent 2% of their time within 100 m of trails, where non-migratory elk spent 0% of their time in the same distance class. Remaining distance class to trails comparisons may be viewed in Table 9. Seasonal break downs by percentage of data points in each distance class may be viewed in Appendix 14.

Individual elk showed significant differences between distance classes to trails in comparison to their respective migratory group and the entire study group of elk. Migratory elk #28 was found in both the 200-400 m distance class (t_{13} = 0.080, p > .10) and 400-600 m distance classes more than all of the elk in the entire study group (t_{13} = 0.091, p > .10). Non-migratory elk #420 was found in the 200-400 m distance class more than the elk in her migratory group (t_{13} = 0.000, p > .05). The same elk (#420) was found in the >600 m distance class less than the elk in her migratory group (t_{13} = 0.000, p < .05). Migratory elk #421 was found in the 0-100 m distance class more than the elk in the elk in her migratory group (t_{13} = 0.069, p > .10) and the entire study group (t_{13} = 0.016, p > .05). The same elk (#421) was found in the 100-200 m distance class more than the entire study group of elk (t_{13} = 0.037, p > .05). She (#421) was found in the 400-600 m distance class more than all of the elk in the entire study group (t_{13} = 0.057, p > .05). Elk #421 was less likely to be found in the >600 m distance class than the elk in the entire study group (t_{13} = 0.052, p < .10). Migratory elk #422 was found within 100 m of trails more than the entire study group of elk (t_{13} = 0.036, p > .05). The same elk was found in the 100-200 m distance class (t_{13} = 0.036, p > .05) and 200-400 m distance class (t_{13} = 0.033, p > .05) more than the entire group of elk in the study. She (#422) was also found in the 400-600 m distance class more than the elk in the entire study group (t_{13} = 0.073, p > .10). Elk #422 was less likely to be found in the >600 m distance category than the rest of the elk in the entire study group (t_{13} = 0.040, p < .05).

Habitat Use with Season and Season and Time as Predictors

Regression analysis was performed to determine if season and/or season and time of day predicted habitat use by migratory elk versus non-migratory elk. The same analysis was conducted to view differences in habitat use of individual elk.

Group Analysis: Season and/or season and time of day did influence habitat selection per migratory group. At both the 50% and 95% scale levels season and season and time of day predicted habitat use per slope category (% gradient) for migratory elk. At the 50% scale, ordinal logistic regression analysis yielded a significant model that predicted seasonal habitat use of migratory elk to utilize slopes with steeper gradients with a Nagelkerke pseudo R^2 of 0.223, and at the 95% scale with Nagelkerke pseudo R^2 value of 0.248. Similarly, at the 50% scale, ordinal logistic regression analysis yielded a significant model that predicted seasonal habitat use in combination with time of day to predict migratory elk utilization of slopes with steeper gradients with a Nagelkerke pseudo R^2 of 0.232, and at the 95% scale with Nagelkerke pseudo R^2 value of 0.253.

At the 50% scale, season and season/time of day predicted distance to trails for migratory elk. Ordinal logistic regression analysis yielded a significant model that predicted seasonal habitat use of migratory elk relative to distance to trails with a Nagelkerke pseudo R^2 of 0.231. Similarly, at the 50% scale, ordinal logistic regression analysis yielded a significant model that predicted season and time of day habitat use relative to distance to trails of migratory elk with a Nagelkerke pseudo R^2 of 0.231. Finally, at the 95% scale, season and season/time of day predicted distance to paved roads for migratory elk. At the 95% scale, ordinal logistic regression analysis yielded a significant model that predicted seasonal habitat use of migratory elk relative to distance to paved roads with a Nagelkerke pseudo R^2 of 0.239. Also, at the 95% scale, ordinal logistic regression analysis again yielded a significant model that predicted season and time of day habitat use of migratory elk relative to distance to paved roads with a Nagelkerke pseudo R^2 of 0.242.

Individual Elk Analysis: One elk (M #82) demonstrated predictability with regard to season and season/time and aspect of habitat used (Appendix 15). Nine elk showed predictability with regard to season and season/time and slope of habitat used (Appendix 15). Eight of the nine elk were migratory. Very few elk (2 migratory elk) showed predictability with regard to season and season/time and distance to cover of habitat used (Appendix 15). Seven migratory elk showed predictability with regard to season and season/time and distance to non-paved roads of habitat used (Appendix 15). Eight migratory elk showed predictability with regard to season and season/time and distance to paved roads of habitat used (Appendix 15). Six elk showed predictability with regard to season and season/time and distance to shrub habitats used (Appendix 15). Five of the six elk were migratory elk. Six elk showed predictability with regard to season and season/time and distance to trail habitats used (Appendix 15). Five of the six elk were migratory elk. Three migratory elk showed predictability with regard to season and season/time and distance to water habitats used (Appendix 15).

DISCUSSION

Rural mountain areas in the Pacific Northwest are rapidly being discovered and developed as vacation and/or second homes. In addition, these fertile river valley areas such as the upper Cowlitz River Valley, continue to be home to various agricultural practices and livestock ranching. As was the case with the herd in this study and many other elk herds in North America, critical winter range areas are being reduced in size because of human impacts. The results of our study confirm that non-migratory elk not only prefer relatively flat areas, but are prone to be found in open habitats (pasture/clear cuts) at greater distances from cover (safety), and use habitat in closer proximity to paved roads than their migratory herd counterparts. As a result, the non-migratory elk in our study appear to have become habituated to the presence of humans and human activity.

While individual elk often had strong behavioral differences compared to the rest of their group, migratory and non-migratory elk primarily differed in use of flat vs. steep topography, slope preference, abundance near trails, and season/time of day.

The differences detected between individual elk and their respective migratory group and the overall study group of elk were beyond the scope of the study. However, it is important to recognize the differences, as further analysis could show linkages to genetic and or/behavioral factors that may impact the behavior of individual family/social groups of elk within an elk herd.

Home Range

Home ranges on the 53 elk were estimated using the minimum convex polygon (MCP) method for home range analysis and comparisons. Although, other methods for estimating home range are used to yield greater precision, the MCP method is the oldest method that has been commonly used (White and Garrott 1990). For our purposes of comparing home range size between migratory and non-migratory elk, the simplicity, flexibility of shape, and ease of calculation of MCP was ideal. The study areas for both the Randle and Packwood group also used the MCP for the entire sub-herds to determine study area boundaries.

The purpose of the home range area comparisons between migratory and non-migratory elk was to identify differences, if any, in how the two segments of the herd were using the landscape. Elk home range areas central and west of the Rocky Mountains have been reported to span anywhere from 1 km^2 – 90km^2 in size (Schroer 1987). Overall, the collared elk (both migratory and non-migratory) in our study had a combined mean life home range of 61 km^2 (6100 ha), migratory elk life home range was 102 km^2 with a range of 54-102 km^2 annually over the 2004-2008 year period. The non-migratory life home range was 20 km^2 with a range of 5.4-20 km^2 over the 2004-2008 year period. Relative to other studies the home range estimates of this study were similar to range areas of other studies (Jenkins 1980, Pope 1994, Millspaugh 1995, Cole 1996). It is difficult to compare home range areas among different studies since the results will vary based on the method of estimation used as well as the influence of sample sizes on the results. Much analysis and comparisons of home range estimation methods have been conducted (Pope 1994, Witmer 1981, White and Garrott). Still, the non-migratory range areas of this study are very similar to the results of other studies that focused on non-migratory elk. Pope (1994) focused his study on non-migratory elk which had a mean home range of 7.65 km^2 over an approximately 14 month period. Other studies on non-migratory elk using varying methods and sample sizes ranged between 4 km^2 (Witmer 1981), 10 km^2 (Jenkins 1980), and 3 km^2 (Franklin et al. 1975). Many of these studies analyzed data over ~ 12 month periods. Our study included five separate biological years of data for analysis and comparison and also included life home range estimates of the combined five years of data separated out per migratory status. Our non-migratory range areas per biological year yielded similar results to the studies cited above. Mean non-migratory range sizes included the following: 2004 = 8.5 km^2, 2005=5.4 km^2, 2006=11km^2, 2007=11km^2, 2008=14km^2, life home range=20km^2. Mean migratory range sizes included the following: 2004=58km^2, 2005=54km^2, 2006=54km^2, 2007=55km^2, 2008=75km^2, life home range=102km^2. Considering the fact that migratory elk travel greater linear distances to reach high-elevation summer range areas, intuitively we expected that home range areas of migratory elk would be significantly larger and different than non-migratory elk. The results of our home range analysis provide evidence that home range areas between migratory and non-migratory elk were significantly different for the study group of elk.

Migration and Distribution

Anecdotal inferences have been made to explain elk behavior of the South Rainier elk herd (Bradley 1982, WDFW 2002). It was previously thought that a clear delineation could not be made between summer and winter ranges in the South Rainier elk herd area (WDFW 2002). Elk that resided in areas outside of Mt. Rainier National Park were thought to have become non-migratory because of logging practices that opened up expanded habitats favorable to elk (WDFW 2002). Other studies have demonstrated that it has not been uncommon that elk herds may typically have a portion of the population that is migratory and a portion that is non-migratory (Martinka 1969, Craighead et al. 1972, Boyd 1970). This study showed much more variation in elk distribution than previous understandings described. The high fidelity rate of the elk in our study is consistent with other studies where elk showed high range fidelity from year to year (Smith and Robbins 1994, Schwartz and Mitchell 1945). The elk wintering in the upper Cowlitz Basin between Randle and Packwood were previously thought to have either been non-migratory because of forest practices that had changed outside of MRNP or if migratory, migrated to Mount Rainier National Park (WDFW 2002). The results of this study showed that migratory elk were ceasing most opportunities to access quality forage in the sub-alpine areas surrounding the Packwood and Randle study areas.

Survival Rates

Survival rates were similar, but mostly lower in comparison to survival rates of other studies in Oregon (Pope 1994, Stussey 1993). Factors contributing to mortality that may have resulted in lower survival rates included vehicle collision 16%, wounding/ legal harvest/illegal hunting 32%, predator kills 16%, starvation 20%, and high proportions of unknown causes 24%. Legal and illegal hunting and wounds associated with hunting accounted for the highest annual percentage of mortalities. Legal hunting of both male and female elk is allowed during their respective seasons. In response to chronic damage complaints in the agricultural segment of the range, state officials have created damage hunt areas (IE: Game Management Units 503 and 516) where female elk harvest is allowed. Additionally, ≤ 40 female elk are legally harvested by tribal hunting annually. Illegal hunting (poaching) has become a chronic problem for elk in the study area. Poaching has been listed in the South Rainier Elk Herd Plan as the primary limiting factor of the herd (WDFW 2002). Severely reduced State and local governmental budgets have resulted in little, to no, enforcement coverage to address localized poaching problems. With regard to road-kill, the winter range area of the herd has the highest incidence of vehicle-elk collisions in the entire state of Washington (Meyers et al. 2008). The percentage of elk killed by cougars is not unusually high, however, if state sanctioned cougar hunts allowed the use of hounds, the local cougar population impacting the herd would be dramatically reduced. The use of hounds to hunt cougars is prohibited by the State of Washington in the range area of the study. In the case of moralities attributed to starvation, it is not uncommon to have winter-kill numbers in the 15% range. Our mean % of starvation mortalities for the study period was 20%, slightly higher than the acceptable range (Skovlin et al. 2002). The proportion dying from starvation should be viewed carefully and noted that, during two of the four years of the study we experienced La Nina weather conditions. With the La Nina weather system, we received excessive amounts of snow in low elevation areas for extended periods of time. Not only did the extreme winter weather make the elk more vulnerable to legal and illegal hunting, food sources were dramatically reduced. Because of the small sample size for overall annual mortalities (3-10 per year), differences between migratory and non-migratory elk were not analyzed.

Habitat Selection

Aspect

Many studies have shown evidence that elk prefer specific aspects that vary seasonally. Skovlin and others (2002), found that in winter, elk prefered upper south-facing slopes that, because of wind, sun angle (radiation) or shade pattern were the first to become bare of snow. Overall, both migratory and non-migratory elk spent a higher percentage of their time in southern aspects during all four seasons of the year that was analyzed. Witmer (1981) also found similar results in his study of elk in western Oregon. The literature also suggests that elk prefer northern aspects during summer months (Skovlin et al. 2002). Both the migratory and non-migratory groups of elk in this study did not show a preference for north-facing slopes during summer. The migratory elk in this study, showed a preference for south facing slopes regardless of season. In summer the migratory elk mostly spent their time above 5000 ft where temperatures were cooler and still within the elevation range of sub-alpine habitat areas where cover/shade were also abundant. This likely provided relief from warmer temperatures. It could also be that the sub-alpine areas used by the migratory elk in this study remain lush with abundant vegetation throughout the summer regardless of aspect. Although some of the historic studies that have documented patterns of habitat use by elk have shown elk prefer northerly aspects during summer, these studies may have been in areas with arid climates where elk must seek north aspects in search of abundant vegetation (Nelson and Burnell 1975, Julander and Jeffrey 1964). More recent studies have shown even more variation to habitat use and preferences that deviate from what had been considered normal patterns such as southern aspect preference in winter and north-facing preferences in summer (Bracken and Musser 1993). The non-migratory elk in our study spent approximately twice as much of their time in flat aspect habitat areas than the migratory elk. This is not surprising since the river bottom areas that encompass both summer range for non-migratory elk and winter range for the entire herd consists of dense riparian vegetation that provide abundant water, food, and cover. In addition, the flat range areas used by the non-migratory elk in summer include agricultural lands and residential areas with an appealing array of vegetation. Although the regression analysis to detect aspect preferences by season did not show significant correlations, it was possible to view a large data set (>80,000 data points) and observe where the elk were spending their time feeding and bedding. Migratory elk spent 11% of their time in habitat that is considered flat, where NM elk spent 19% of their time in the flat habitat type, NE aspect: M=16%, NM=11%, SE aspect: M=32%, NM=24%, SW aspect: M=16%, NM=28%, NW aspect: M=25%, NM=18% (Table 2). Migratory elk were found to use the SW aspect significantly less than the NM elk group (t_{13}=0.035, p<.10). Based on the results of other studies I expected to see clear patterns of aspect preferences for both summer and winter seasons. The results demonstrated variation in aspect preferences as other studies have done (Pope 1994). Based on the percentage of data point locations, the results also showed differences between aspect preferences of migratory and non-migratory elk.

Slope

Elk have been known to use steeper slopes in summer than in winter (Julander and Jeffrey 1964, Zahn 1974, Marcum 1975, Leege et al. 1975). Although not identified as such, many of the studies that document elk habitat use with slope preferences ranging between 15% - 50% appear to be describing migratory herds, and/or migratory segments of particular elk herds. The results showed that migratory elk preferred steeper 30-45% and >45% slopes more than non-migratory elk at both the 50% and 95% scales. In addition, the results showed that season predicted habitat use of migratory elk use of habitat slopes with steeper gradients. These results are similar to Marcum (1975) who found that elk on summer range preferred moderately steep slopes – 27% to 58%. Studies in north-central Idaho, also found that elk on summer range tend to use 20-40% slopes up to 60% as seasons progressed (Leege et al. 1975, Hershey and Leege 1982). Typically, slopes > 20% correlate with sub-alpine and alpine habitat types in our study area. Sub-alpine and alpine habitat in summer provides the best quality and quantity of forage, in addition to abundant cover for migratory elk. The disparity in slope preferences between migratory and non-migratory elk in our study demonstrates optimal habitat use based on behavior. Non-migratory elk in this study preferred 1-15% slopes more than migratory elk. The areas encompassing summer range that are 1-15% in slope are river bottom areas rich in riparian forage, with abundant cover and water. The areas < 15% also include agricultural areas in the river bottom, which are also desirable to elk. The adjacent slopes >15% slopes are dense evergreen forest areas of Gifford Pinchot National Forest. The dense canopy cover of trees in this area does not allow sunlight to penetrate the forest floor to stimulate under-story growth of plant communities that elk prefer for browse. In other words, the forage in the > 15% slope areas of the non-migratory elk range would be of lower quality and quantity. Tree overstory and canopy coverage are primary determinants of understory herbage productivity (Skovlin et al. 2002). High degrees of canopy closure often equate to little or no elk food under the canopy (Skovlin et al. 2002).

Cover

Cover is considered to be an important component to elk survival for both the thermal benefits contributing to temperature regulation and hiding or escape cover. Studies in Washington State do not support the hypothesis that elk require forest cover in summer to maintain body temperatures, at least in Pacific coastal climates (Skovlin et al. 2002, Merrill 1991).

I analyzed my data with a view to determine if cover and distances to cover were important per migratory group primarily for security/hiding and escape cover. Migratory elk in this study spent 51-56% of their time within the 0-50 m distance class of cover where the non-migratory elk spent 35-44% of their time within the same distance class. Seasonally, during winter migratory elk spent 57%-61% of their time within 50 m of cover as compared to non-migratory elk which spent 34%-39% of their time within 50 m of cover. In addition, the results of *t tests* showed that migratory elk preferred to be within 50 m of cover in winter more than the non-migratory elk. An explanation for this behavior could be that the migratory elk were less habituated to humans and human presence than the non-migratory elk. Therefore, while on winter range, migratory elk tended to be within 50 m of escape cover more than non-migratory elk. In summer, there was no disparity between the percentages of data points per migratory group per distance classes. This could have had to do with the fact that while migratory elk were on summer range, being in close proximity to escape cover was not as important for a couple reasons. First, much of summer range was within National Park, Monument, and/or Forest Service lands where human disturbance was reduced or limited. Second, there were no hunting seasons during summer, unlike winter where hunting seasons did occur annually.

Shrub

The greatest percentage of the study data points for both migratory and non-migratory elk fell within the 50 m distance class of the shrub/scrub habitat types. This type of habitat may be referred to as an ecotone where different types of vegetation are juxtaposed, which include high frequencies of early successional communities which are important components of elk habitat (Skovlin et al. 2002). Levels of elk activity have been known to decrease with increased distance from the interface of forest and non-forest communities (Marcum 1975, Winn 1976, Leckenby 1984). Studies in the Wasatch Mountains of Utah demonstrated that both frequency of plant species and herbage biomass at an edge was two times greater than 46 m into a meadow (Winn 1976). This data showed migratory elk preferred ecotone/edge habitats (0-50 m) >83% of the time in summer and >52% of the time throughout the rest of the year. One non-migratory elk fell within this distance class >59% of the time in summer and >32% of the time the rest of the year. Greater than 96% of our data points for both migratory and non-migratory elk fell within 600 m of the shrub scrub habitat type for all seasons. Also of interest was that 89% of the data points for both migratory groups fell within the 400 m distance class during summer. Leckenby (1984) found that at least 80% of elk use in summer forage areas occurred within 274 m edge ecotone areas in the Blue Mountains of Oregon. In the 50% range areas, migratory elk spent 65% of their time in the 0-50 m range of shrub/scrub while NM elk spent 58% of their time in the same distance class.

Water

Studies from various regions of the northwest suggest elk prefer summer habitats within 800 m of water (Bracken and Musser 1993, Jeffrey 1963, Mackie 1970, Marcum 1975). Greater than 78% of the elk locations were within 600 m of water in summer for both migratory and non-migratory elk. Even though my data is consistent with other findings, many of these studies appear as though they were in climates that tended to be semi-arid. What appeared to be somewhat unusual was that I had the greatest frequency of elk found in distances greater than 600 m during summer than other seasons throughout the year. The greater number of elk points in this distance class during summer could be the result of temporal differences rather than an overall statement of water preferences. The summer of 2008 was unusually cool which could have slowed snow melt in upper alpine and sub-alpine areas utilized by the migratory elk. In that case, snow melt in these areas often times provides temporary water sources in the form of shallow alpine depressions where the snow has melted. Since these water sources are not included in the water inventory they would not show up in the analysis. It is clear that water sources and associated riparian habitats are important to elk in this study based on the data points. Riparian habitat not only provide natural travel corridors, they have greater plant diversity, and possess different microclimates from surrounding areas due to increased humidity, consequently providing relief from temperature extremes (Oakley et al. 1985, Thomas et al. 1979) The data showed that both migratory segments of the herd I studied had very similar preferences for water and riparian habitats. Habitat use in proximity to water may fluctuate temporally, however, this physiological need of elk to utilize these habitats appeared to transcend migratory behavior.

Roads and Trails

Of all the factors related to logging, the construction of roads and the subsequent vehicle traffic on those roads has proved to be the most significant modification of elk habitat (Lyon and Christenson 2002). Not only do roads have a tendency to collect debris and impede elk movement they also facilitate human access/contact with elk. Elk have been known to avoid human disturbance and/or roads (Irwin and Peek 1979, Lyon 1979, Hershey and Leege 1982). The development of many roads have been sighted in topographic locations that were previously used as wildlife travel routes (Skovlin et al. 2002). As a result, many migration routes have been fragmented and/or have accelerated rates of auto-collisions with wildlife crossing paved roads have occurred. In fact, SR 12 that bisects the winter range has the highest rate of auto-collisions with elk in Washington State (Meyers et al. 2008). My analysis viewed elk habitat use and its associated distances to roads in three categories which were: distance to paved roads, non-paved roads, and trails. This discussion has therefore been broken down by road type category as follows.

Paved Roads

Overall, non-migratory elk spent a greater percentage of their time within 600 m of paved roads than migratory elk. One caveat to note is that State Route 12 runs parallel to the Cowlitz River which runs through the heart of the winter range area and is mostly within 600 m of the river. During the winter months the elk are typically found in the river bottom areas between the Packwood sub-area and the Randle area. In light of that fact, it does not seem unusual that migratory and non-migratory elk would be using winter habitat areas similarly. The other seasons showed greater variation between the migratory groups, primarily during summer. Many of the winter range areas that are within 600 m of paved roads also fall within no-shoot zones. It could also be that the herd as a whole did not experience security issues when using habitat areas within 600 m of paved roads in winter because many of these areas are designated no-shoot zones. Migratory elk spent 13-18% of their time within 600 m of paved roads during summer whereas non-migratory elk spent 45-55% of their time within the same distance class. Explanation for the differences during summer could be that there are very few paved roads, if any, within 600 m of the sub-alpine and alpine habitat areas utilized by migratory elk. Since the non-migratory elk remain in areas more populated by humans with associated development and infrastructure (roads etc.), it would be an intuitive assumption to predict non-migratory elk may be more habituated to the presence of humans and roads, and as a result be found more often in closer proximity to paved roads than migratory elk. However, migratory elk were also found to avoid the 0- 600 m distance class of paved roads both during spring and fall seasons more than their non-migratory counterparts. The data show migratory elk avoiding habitat areas within 600 m of paved roads more than non-migratory elk, with the exception of the winter season. The results of the data must be viewed carefully to avoid potential misleading cursory summations of what the data may be demonstrating.

Non-Paved

Overall, both migratory and non-migratory elk avoided non-paved roads to a greater extent cumulatively throughout the year. What was also clearly demonstrated in the data, was that both migratory and non-migratory elk avoided using habitat within 200 m of non-paved roads >80% of the time. This supports the literature that states elk avoid areas nearest roads (Lyon and Christensen 2002). Non-paved roads are the most travelled roads/paths for vehicles to access hunting grounds on public and non-public lands in our study area. It is therefore not surprising to see that elk avoid habitat areas within 200 m of the non-paved roads and that they are in fact found at distances >600 m most of the time. Also, most of the non-paved roads within our study area were outside of most no-shoot zones that prohibit hunting which stands to reason that both segments of the herd would be wary to place themselves within shooting distance of the non-paved roads. Seasonally, habitat use patterns were fairly similar between the migratory and non-migratory elk groups.

Trails

There were statistically significant differences between the migratory and non-migratory elk at the 95% home range scale. However, it must be noted that trails within the study area were only relative during summer months, and mostly only present in the migratory elk habitat areas. Therefore, the analysis has been included but should be used carefully when considering behavioral differences between migratory and non-migratory elk in this area. No differences were detected between the migratory and non-migratory groups of elk in relation to habitat used near trails in the 50% range areas. However, at the 95% scale, differences were detected between the migratory and non-migratory groups of elk in relation to habitat used near trails.

MANAGEMENT IMPLICATIONS

The South Rainer elk herd plan (2002) calls for more information on the movements and wintering areas of the herd. This study identified three separate wintering areas of elk considered part of the South Rainier elk herd. The three wintering areas were along the upper-Cowlitz River in the Packwood area, upper-Cowlitz River in the Randle area, and the lower Cispus drainage just south of Randle near the town of Cispus. The Cispus wintering area was combined with the Randle range area because of its close proximity to the Randle group. To start with, the land ownership in the Cispus drainage area consisted of a combination of small ranches and homesteads, industrial timberlands, and portions of the Gifford Pinchot National Forest. Very few, if any elk damage complaints have been reported in this area. However, elk damage complaints in both the Packwood and especially in the Randle range areas along the Cowlitz have been common. One of the biggest challenges for the sustainability of this herd is landowner tolerance of elk on winter range. This study may be used to identify ideal areas for conservation of winter range. The defining boundary that we used between the Packwood and Randle range areas was the Cora Bridge located where SR 12 crossed the Cowlitz River between Packwood and Randle. This study showed that there was very little, if any mixing between the Packwood and the Randle groups. One elk that primarily wintered in the Packwood Range area (95%) was known to move southwest of the Cora Bridge into the Randle sub-area 5% of the time in winter. The non-migratory segment of the herd in the Randle range area have been known to cause summer crop damage and as a result have been targeted by state officials for removal (WDFW Issue 10/42, WA Fish and Wildlife Commission Minutes, 2009).

The results of this study provide detailed information on the herd with added insight on how the herd uses the range. As human encroachment into elk range continues to increase, planning for, protecting and securing critical habitat such as winter range is imperative. Responsible management of wildlife needs to be closely tied to practicing ethical stewardship, and a responsibility to live with wildlife rather than resorting to lethal removal when the wildlife we encounter become inconvenient. Land acquisition with a goal of creating winter refuge areas is needed in both the Packwood and Randle range areas. Elk in these two locations have become a popular roadside attraction to tourists travelling through the area. Development of elk refuges in these locations could benefit elk by preserving critical habitat, and serve to promote local tourism by incorporating elk viewing and interpretive information of the local elk and other local fauna.

Home range areas between the migratory and non-migratory elk were significantly different. As predicted, the home ranges of the migratory elk were much larger than the non-migratory elk. Critical habitat for non-migratory, migratory, and the elk herd as a whole have been identified as a part of this study. Some of the other differences between the migratory and non-migratory elk with regard to habitat use preferences were illuminating. Migratory elk were found in closer proximity to cover more often than non-migratory elk. Migratory elk also selected habitat areas at greater distances to paved and non-paved roads than non-migratory elk. These data reinforce the view that non-migratory elk tend to be more habituated to humans and human disturbance. Land managers should continue to seek opportunities to increase forage enhancement projects on surrounding U.S. Forest Service lands, WA DNR lands, and industrial timberlands. In addition, an effort should be made to work with landowners in damage-prone areas of winter range to develop incentives for conservation easements to enhance and maintain elk habitat, in addition to allowing elk use of their property.

These results contribute to the body of knowledge describing home range sizes of elk in the region of our study, and habitat preferences with regard to distances to roads, cover, and use of aspect and sloped habitats per season. The elk in this study avoided habitat areas within 600 m of paved roads the majority of the time and avoided habitat areas within 200 m of non-paved roads the majority of the time. Management activities including road closure opportunities in critical winter habitat areas should be pursued to minimize disturbance to elk during winter. Cover for security was important to non-migratory elk and even more so for migratory elk. Proximity to cover during summer was not as important to elk as it was during other seasons, especially during winter. If future habitat improvements are made on winter range, consideration must be made in providing escape cover within distances of 200 m of the habitat enhancements.

Differences in behavior and habitat use were detected between migratory elk and non-migratory elk. Based on this analysis, non-migratory elk do appear to have become more habituated to the presence of human activity. The results of this study demonstrate similar migratory patterns in terms of proportions of elk that are migratory and non-migratory within the same herd (Craighead et al. 1972, Martinka 1969). With an interest to manage and maintain the herd in a holistic way, it is important to avoid short-sighted management decisions in response to damage complaints that, in many instances could result in elimination of non-migratory segments of populations. Targeting segments of a population such as the non-migratory portion of a herd obscures the natural migration pattern and understanding of the respective herd (Irwin 2002). The non-migratory elk tended to use habitat areas that were relatively flat (62% of the time) indicating that flat river bottom areas were important habitat year around. The non-migratory elk tended to use habitat areas in the river-bottoms as well as adjacent upland areas on both north and south facing slopes. The summer range areas used by the migratory elk are fairly abundant in quantity and quality of forage. Although the non-migratory portion of the herd is relatively small in numbers, it could negatively impact forage availability for the entire herd in winter. On ranges occupied by elk during summer and winter, summer use of important forage plants by elk can reduce forage supplies during winter (Martinka 1969). However, studies of domestic cattle light spring grazing may have improved forage quality in winter range areas (Anderson and Scherzinger 1975). Protection of winter range areas remains of particular concern to both WDFW and Tribal wildlife managers. The concern is not so much non-migratory elk degrading conditions on what will also be winter range by the collective herd, as much as conflicts with existing agricultural land users, and increasing development within the winter range areas. Planning for the sustainability of the herd must focus on issues that have been raised around winter range. Securing of funds to address chronic damage to agricultural lands incurred by non-migratory elk in summer would be useful. In addition, funding for elk-proof fencing in chronic damage prone agricultural lands would also help. Long-term solutions would include land acquisition on winter range with a goal of creating elk refuges both in the Randle and Packwood areas. Although very similar in the way both migratory and non-migratory elk use the landscape, the data show non-migratory elk using primarily river-bottom areas in closer proximity to human activity. The non-migratory elk are seizing opportunities to exploit the best habitat possible, which is frequently in agricultural areas. Core home range areas were in flat habitat areas with regard to aspect 62% of the time.

Wildlife over and under passes have been successful in reducing wildlife mortalities as the result of auto-collisions in other portions of the state of Washington (I-90 corridor near Snoqualmie Pass) and in areas of Canada near the town of Banff. Use of these data to plan for wildlife crossings bisecting SR 12 would help reduce elk mortalities and auto-collisions in the winter range area.

The three primary goals of the WDFW South Rainier elk herd plan state the following: to manage the elk herd for a sustained yield; to manage elk for a variety of recreational, educational, and aesthetic purposes including hunting, scientific study, cultural and ceremonial uses by Native Americans, wildlife viewing and photography; and to manage and enhance elk and their habitats to ensure healthy, productive populations. Tribal wildlife managers also share these goals for the South Rainier elk herd. To achieve these goals in planning for the sustainability of the elk herd, legal harvest must also continue to be carefully regulated using the best available science to steer management decisions.

Finally, although this study contributes to a greater understanding of the movements and habitat preferences of the South Rainier elk herd, and ultimately to a larger body of knowledge on elk ecology, further studies on the herd could be useful. For example, supplemental research with a focus on bull habitat preferences would be especially useful in understanding the entire elk herd. Also, radio-collaring additional cow elk in the Randle area will be important to continue to gather more information on the habitat use and distribution of the migratory elk that winter in this area.

REFERENCES

Ager, Alan A., Bruce K. Johnson, John W. Kern and John G. Kie. 2003. Daily and Seasonal Movements and Habitat Use by Female Rocky Mountain Elk and Mule Deer. Journal of Mammalogy 84: 1076-1088.

Bender, Louis, Gary J. Roloff and Johnathan B Haufler, 1996. Evaluating Confidence Intervals for Habitat Suitability Models. Wildlife Society Bulletin 24:347-352.

Bender, L. C., and R. D. Spencer. 1999. Estimating elk population size by reconstruction from harvest data and herd ratios. Wildlife Society Bulletin 27:636-645.

Bender, V. 1962. Memorandum to Superintendent, October 23. Mount Rainier National Park Files.

Berkes, Fikret. 1990. Sacred Ecology: Traditional Ecological Knowledge and Resource Management. Taylor and Francis, Philadelphia, PA, USA.

Beyer, E. and Jonathan B. Haufler. 1994. Diurnal versus 24-Hour Sampling of Habitat Use. The Journal of Wildlife Management 58:178-180.

Bookhout, Theodore A. Editor. 1996. Research and management techniques for wildlife and habitats. Fifth ed., rev. The Wildlife Society, Bethsda, Md. 740pp.

Boyce, M. S. 1989. The Jackson elk herd: Intensive wildlife management in North America. Cambridge Univ. Press, New York, 306 pp.

Bracken, E. and J. Musser. 1993. Colockum elk study. Compl. Rept. Washington Dept. Wildlife, Olympia. 129 pp.

Bradley, W. P. 1982. History, ecology, and management of an introduced wapiti population in Mount Rainier National Park, Washington, Ph.D. Thesis, Univ. Washington, Seattle. 274pp.

Brown, C. 1985. The Sand Creek elk, northeastern Idaho-population status, movements, and distribution. Idaho Dept. Fish Game Proj. no. W-160-R. 119 pp.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Demarais, Stephen and Paul R. Krausman, 2000. Ecology and Management of Large Mammals in North America. Prentice-Hall Inc. 32, 694-726.

Edge, W. Daniel, C. Les Marcum and Sally L Olson-Edge. 1988. Summer Forage and Feeding Site Selection by Elk. The Journal of Wildlife Management 52:573-577.

Edge, W. Daniel, C. Les, Marcum and Sally L Olson-Edge. 1987 Summer Habitat Selection by Elk in Western Montana: A Multivariate Approach. The Journal of Wildlife Management 51:844-851.

Franklin, J. F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-8. 417pp.

Franklin, J. F., W.H. Moir, M. A. Hemstrom and S. Greene. 1979. Forest Ecosysems of Mout Rainier National Park. U. s. Department of Agriculture, U. S. Forest Service, Proposed P. N. W. Res. Paper (review draft): 221 pp.

Gilbert, Brian A. and Barbara J.Moeller. 2008. Elk sightability bias of aerial surveys during winter in the central Cascades. Northwest Science 82:222-228.

Gove, P.B., ed. 1969. Webster's Seventh New Collegiate Dictionary. G. and C. Merriam Co., Springfield, Massachusetts. 1,221 pp.

Henderson, J. A. 1974. Composition, Distribution, and Succession of Subalpine Meadows in Mount Rainier National Park. Ph. D. Dissertation. Oregon St. Univ., Corvallis: 67pp.

Irwin, L.L. and J. M. Peek. 1983. Elk habitat use relative to forest succession in Idaho. The Journal of Wildlife Management 47:664-672.

Irwin, L. L., J. G. Cook, R. A. Riggs and J. M. Skovlin. 1994. Effects of long-term grazing by big game and lives stock in the Blue Mountains forest ecosystems. U.S. For. Serv. Gen. Tech. Rept. PHW-GTR-325. Portland, Oregon. 49 pp.

Hines, W. W., J. C.Lemos and N. A Hartman. 1985. Male breeding efficiency in Roosevelt elk in Southwestern Oregon. Oregon Dept. Fish and Wildl., Wildl. Res. Rept. No. 15.

Holthausen, Richard S., Michael J.Wisdom, John Pierce, Daniel K. Edwards and Mary M.Rowland, 1994. Using Expert Opinion to Evaluate a Habitat Effectiveness Model of Elk in Western Oregon and Washington. Pacific Northwest Research Station, General Technical Report, U.S. Department of Agriculture, Forest Service: 1-29.

Kennedy, J.S. 1985. Migration, behavioural and ecological. In: Rankin, M.A. (ed.) Migration: Mechanisms and Adaptive Significance. Contributions in Marine Science 27 (supplement), 5–26.

Kufield, T. P. 1973. Foods eaten by the Rocky Mountain elk. Journal of Range Management 26: 106-112.

Leban, F. A., and E. O. Garton. 2000. Program Aerial Survey 2000, Version 1.00, Beta 6.1.4, February 12, 2000.

Lovaas, A. L. 1970. People and the Gallatin elk herd. Montana Fish and Game Department, Helena. 44pp.

Lyon, L. J. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry 81:592-595.

Lyon, L. J. 1979. Habitat effectiveness for elk as influenced by roads and cover. Journal of Forestry 79:658-660.

Lyon, L. J., and P.F Stickney. 1966. Two forest fires and some specific implications in big game habitat management. Proc. West. Assoc. State Game and Fish Commission 46:355-375.

Mech, L. D. 1983. Handbook of animal radio-tracking. University of Minnesota, Minneapolis, USA.

Meyers, W.L, W.Y. Chang, S. S. Germaine, W.M. Vander Haegen and T.E. Owens. 2008. An analysis of deer and elk collision sites along State Highways in Washington State. Completion Report, Washington Department of Fish and Wildlife Report. Olympia, WA 40p.

Mills, Powatten. 2010. Personal Communication. Puyallup Tribal Hunting Commission Member, Puyallup Tribe of Indians, Tacoma, Washington.

Picton, H. D. and I. E. Picton. 1975. Saga of the sun-A history of the Sun River elk herd. Montana Dept. Fish and Game, Helena. 55pp.

Quimby, D. C., and J. E. Gaab. 1957. Mandibular dentition as an age indicator in Rocky Mountain elk. Journal of Wildlife Management 21: 435-451.

Risenhoover, K. L., and R. O. Peterson, 1986. Mineral licks as a sodium source for Isle Royale moose. Oecologia 71:121-126.

Rost, G.R., and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43:634-641.

Rowland, M. M., M. J. Wisdom, B. K. Johnson, and J. G. Kie. 2000. Elk distribution and modeling in relation to roads. Journal of Wildlife Management 64:672-684.

Roloff, Gary J., Joshua J.Millspaugh, Robert A Gitzen, and Gary C. Brundige. 2001. Validation Tests of a Spatially Explicit Habitat Effectiveness Model for Rocky Mountain Elk. The Journal of Wildlife Management 65:899-914.

Sawyer, Hall, Ryan M.Nielson, Fred G.Lindzey, Lorraine Keith, Jake H Powell, and Anu A.Abraham. 2007. Habitat Selection of Rocky Mountain Elk in a Nonforested Environment. Journal of Wildlife Management 71:868-874.

Schullery, P. 1984. A history of native elk in Mount Rainier National Park: final report to National Park Service, Mount Rainier National Park.

Skovlin, J.M., P. Zager and B.K. Johnson. 2002. Elk habitat selection and evaluation. Pages 531-555 in J.W. Thomas and D.E. Toweill, editors. North American Elk: Ecology and Management. Smithsonian Institution Press, Washington, D.C., USA.

Smith, Marion W. 1940. The Puyallup – Nisqually. Columbia University Press. 25,100-101.

Spencer, R. and L.C. Bender. 1997. A population and demographic assessment of the Mount Rainier National Park elk herd. Unpubl. doc., Wash. Dept. Fish and Wildl., Reg. 4, Mill Creek. 5pp.

Spencer, R. and L.C. Bender. 1999. Estimating elk population size by reoncstruction from harvest data and herd ratios. Wildlife Society Bulletin 27:636-645.

Steinhorst, R. K., and M. D. Samuel. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415-425.

Thomas, Jack W., Donavin, A.Leckenby, Mark Henjum, Richard J.Pedersen, Larry D. Bryant, 1988. Habitat Effectiveness Index for Elk on Blue Mountain Winter Ranges. Pacific Northwest Research Station, General Technical Report, U.S. Department of Agriculture, Forest Service: 1-22.

Thomas, Jack W., C. Maser and J.E. Rodiek. 1979. Edges. Pages 48-59 in J. W. Thomas, ed., Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. Handbook No. 533. USDA, Portland, Oregon. 512pp.

Thompson, E. 1981. Mount Rainier National Park Washington Historic Resource Study. National Park Service Center Denver Service Center.

Thomson, A. Landsborough. 1926. Problems of bird-migration. H.F. & G. Witherby, London, pp3.

Toweill, Dale E. and Jack Ward Thomas. 2002. North American Elk Ecology and Management. Smithsonian Institution Press. 12, 531-536.

Treaty of Medicine Creek, December 26, 1854 (10 Stat. 1132).

Unsworth, J. W., F. A. Leban, E. O. Garton, D. J. Leptich and P. Zager. 1999. Aerial Survey: User's Manual. Idaho Department of Fish and Game, Boise, Idaho, USA.

Washington Department of Fish and Wildlife. 1996. Final environmental impact statement for the Washington State management plan for elk. Wildl. Manage. Prog., Wash. Dept. Fish and Wildl., Olympia. 217pp.

Washington Department of Fish and Wildlife. 1997. Draft South Rainier Elk Herd Plan. Olympia, Washington. 12pp.

Washington Department of Fish and Wildlife. 1998. 1997 Game Harvest Report. Wildl. Mange. Prog., Wash. Dept. Fish and Wildl., Olympia. 114pp.

Washington Department of Fish and Wildlife. 1999. 1998 Game Harvest Report. Wildl. Manage. Prog., Wash. Dept. Fish and Wildl., Olympia. 110pp.

Washington Department of Fish and Wildlife. 2000. Draft South Rainier Elk Herd Plan. Olympia, WA, June 9, 2000.

Washington Department of Fish and Wildlife. 2002. Washington State Elk Herd Plan, South Rainier Elk Herd, Wash. Dept. Fish and Wildl., Olympia, 39pp.

Washington Department of Fish and Wildlife, Issue 10/42. Retrieved December 16, 2010 from WDFW Web site: http://wdfw.wa.gov/hunting/regulations/seasonsetting/public_meeting_posters_v3_final.pdf.

Washington Department of Fish and Wildlife: Enforcement. 2009. Unpublished elk nuisance report, Wash. Dept. of Fish and Wildl., Olympia, WA.

Washington Fish and Wildlife Commission. (2009, March 6-7). Meeting of the Fish and Wildlife Commission.

Witmer, G.W. and D.S. DeCalesta. 1983. Habitat Use by Female Roosevelt Elk in the Oregon Coast Range. The Journal of Wildlife Management 47:933-939.

APPENDICES

Appendix 1. Winter range plant list for Western Hemlock zones (Franklin and Dyrness, 1973).

Western Hemlock zone

Overstory species	Understory species	Herb layer
Pseudotsuga menziesia	*Taxus brevifolia*	*Linnaea borealis*
Tsuga heterophylla	*Holodiscus discolor*	*Trillium ovatum*
Acer macrophyllum	*Acer circinatum*	*Adenocaulon bicolor*
	Berberis nervos	*Chimaphila umbellate*
	Gaultheria shallon	*Polystichum munitum*
	Vaccinium parviflora	*Oplopanax horridus*
	Rubus ursinus	

Appendix 2. Summer range plant lists for Pacific Silver and Mt. Hemlock zones (Franklin and Dyrness, 1973).

Pacific Silver fir zone

Overstory species	Understory species	Herb layer
Abies amabilis	*Vaccinium alaskaense*	*Cornus Canadensis*
Abies procera	*V. Ovalifolium*	*Clintonia uniflora*
Tsuga heterophylla	*Berberis nervosa*	*Pyrola secunda*
Pseudotsuga menziesii	*Acer circinatum*	*Achlys triphylla*
	Rubus lasiococcus	*Xerophyllum tenax*
	Gaultheria shallon	*Linnea borealis*
		Tiarella unifoliata

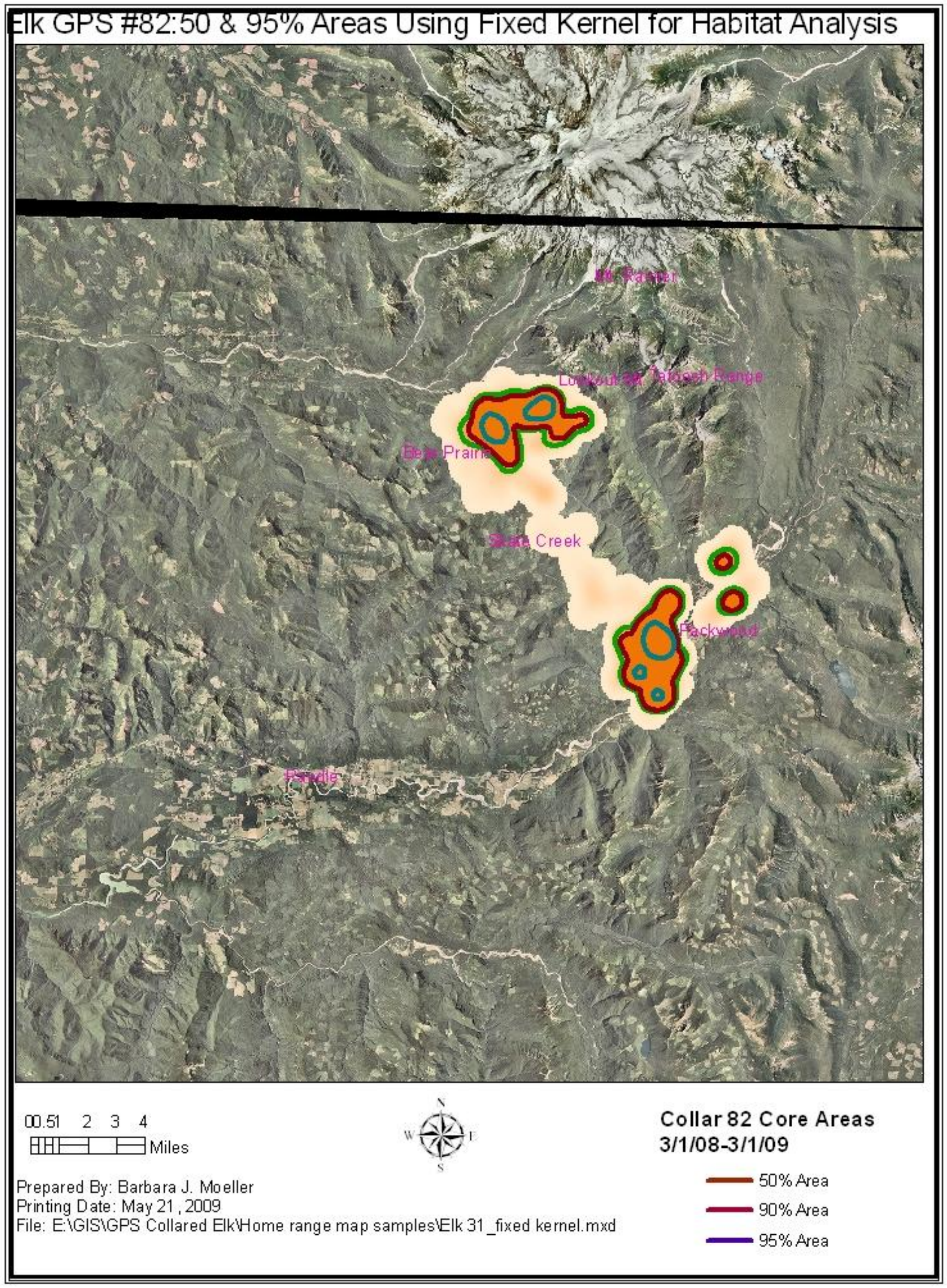
Mt. Hemlock zone

Overstory species	Understory species
Tsuga mertensiana	*Vaccinium membranaecum*
Abies lasiocarpa	*V. alaskaense*
A. Amabilis	*V. Ovalifolium*
Chamaecyparis nootkatensis	*Rhododendron albiflorum*
Pinus monticola	*Menziesia ferruginea*
P. albicaulis	*Rubus lasiococcus*
Picea engelmannii	

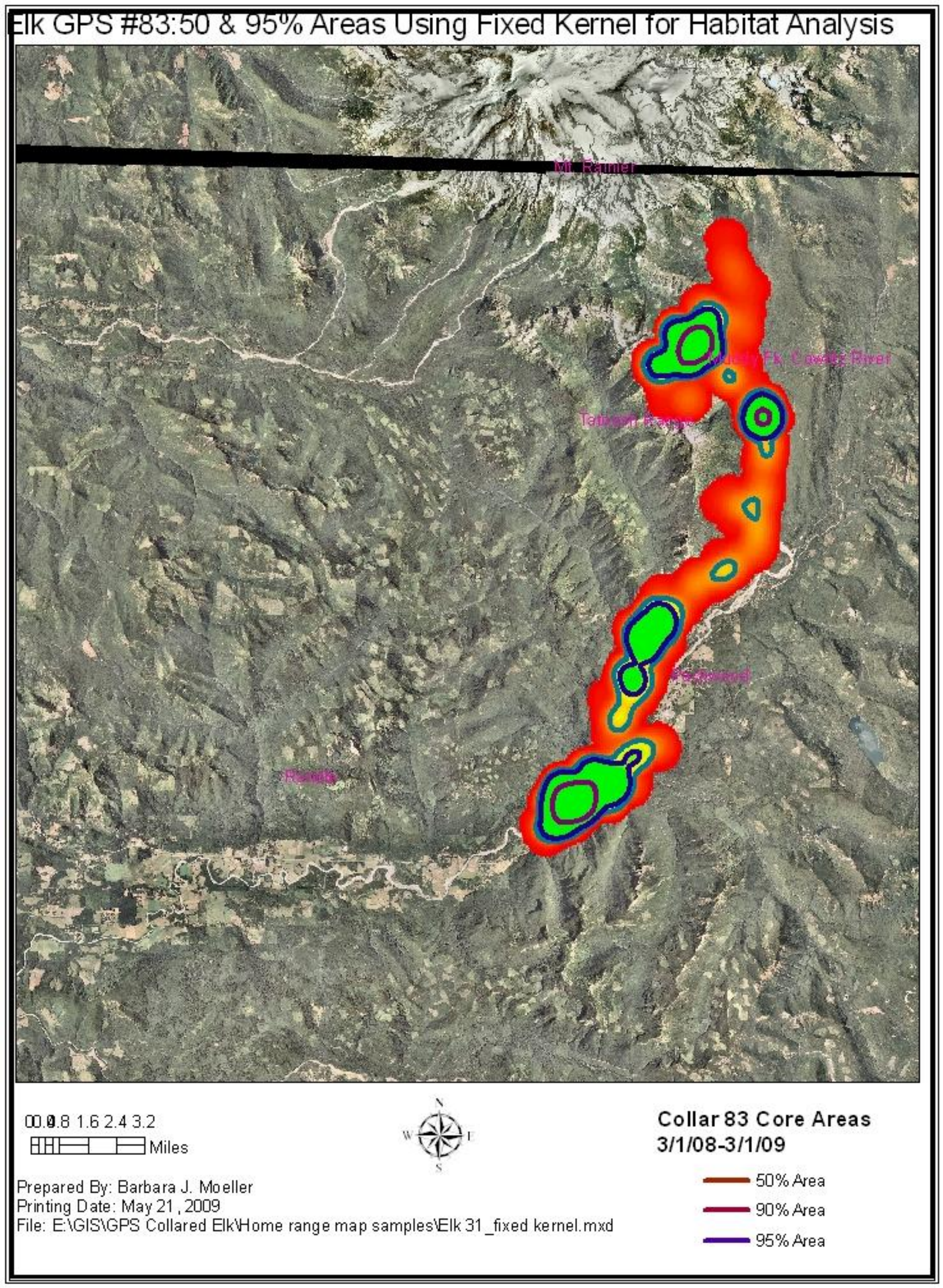
Sub-alpine meadow

Understory species	Herb layer	Grass and Sedge species
Phyllodoce empetriformis	*Valeriana sitchensis*	*Festuca viridula*
Cassiope mertensiana	*Lupinus latifolius*	*Carex spectabilis*
Vaccinium deliciosum	*Veratrum viride*	*C. nigricans*
Phlox diffusa	*Polygonum bistortoides*	
	Aster ledophyllus	
	A. alpigenus	
	Ligusticum grayi	
	Castilleja parviflora	
	Anemone occindentialis	
	Potentilla flabellifolia	
	Arnica latifolia	
	Luetkea pectinata	
	Antennaria lanata	

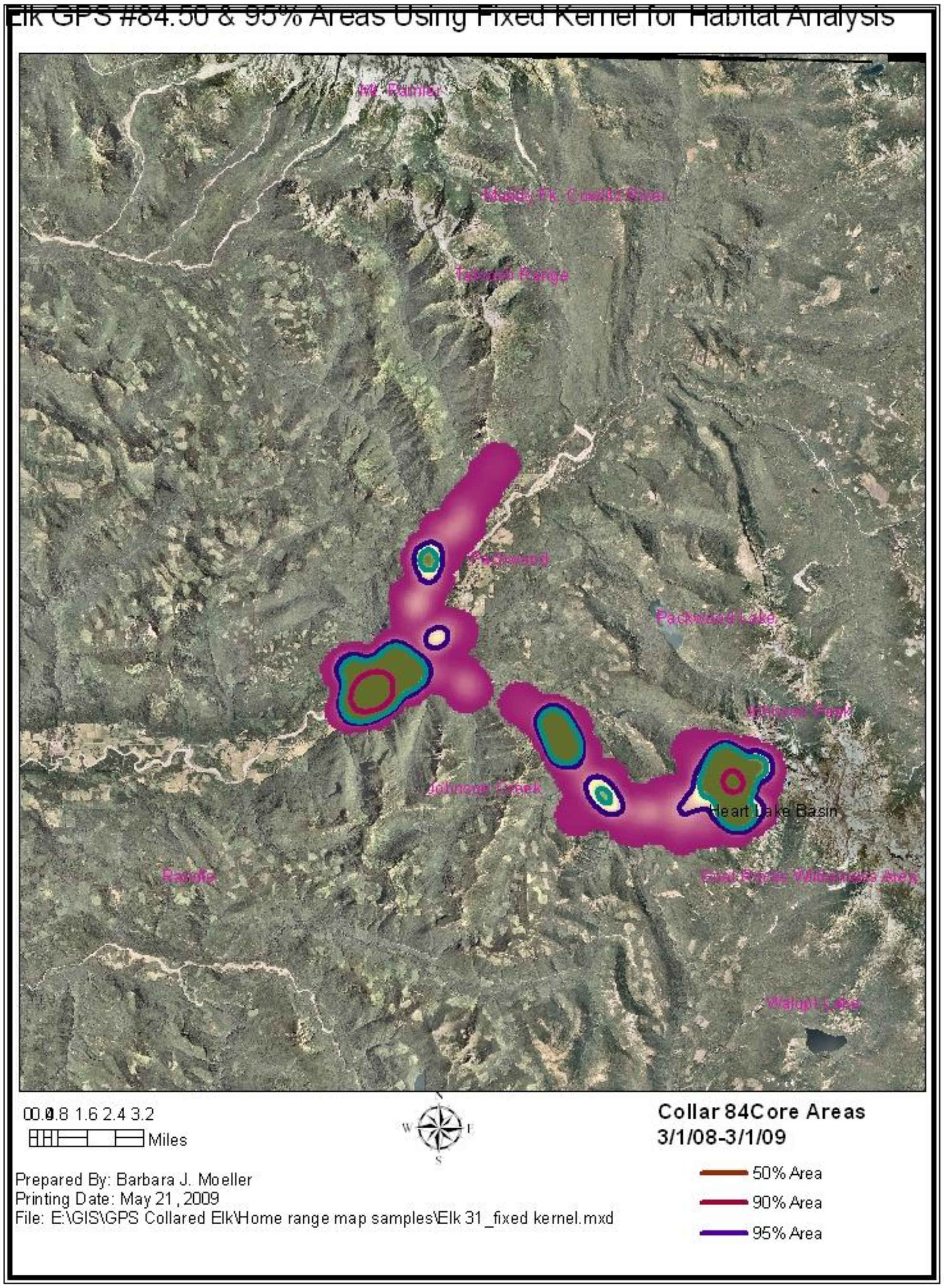
Appendix 3. Collar 82 Batch fixed kernel density at the 50, 90 &95% range areas



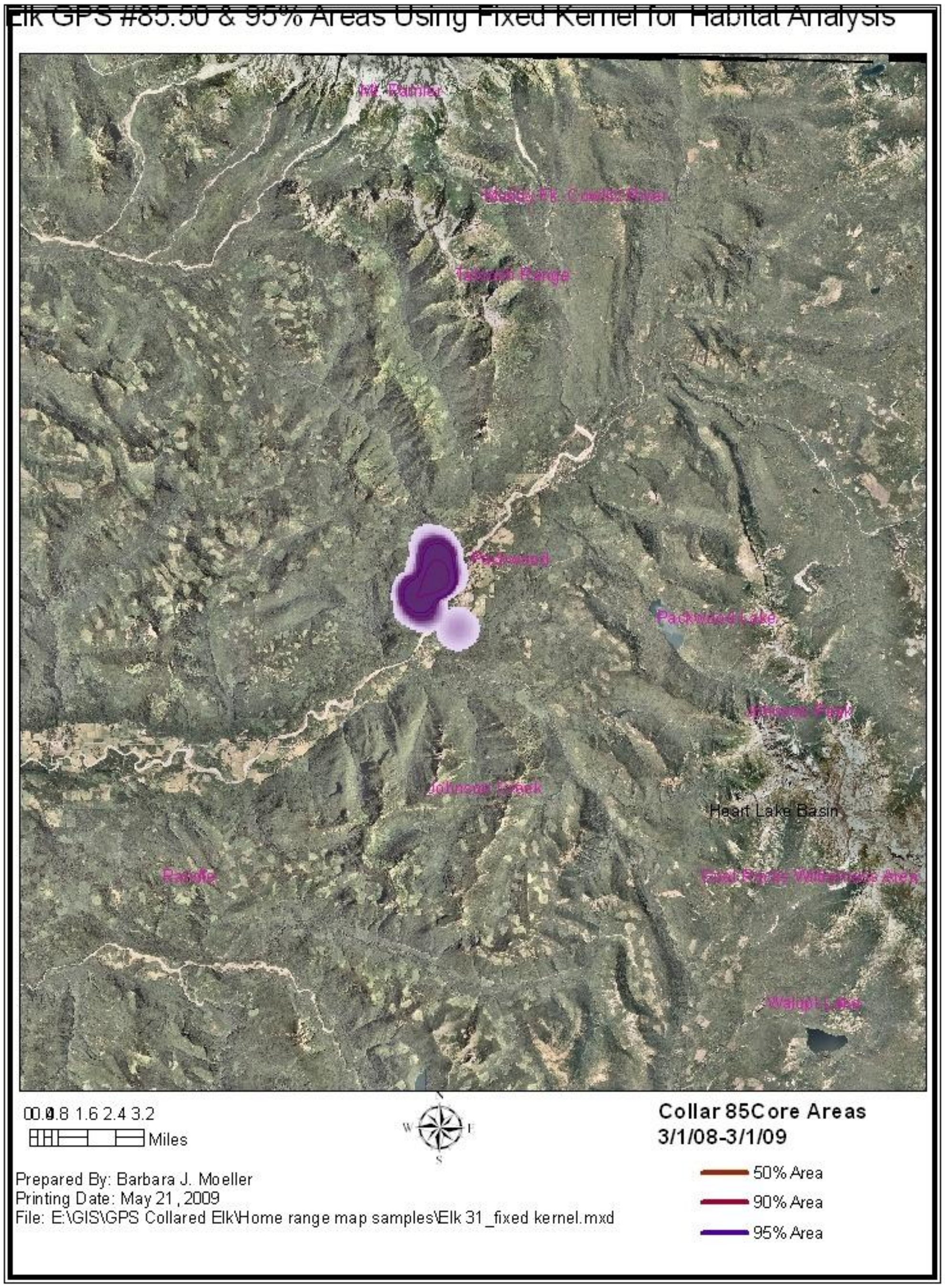
Appendix 3. Collar 83 Batch fixed kernel density at the 50, 90 &95% range areas



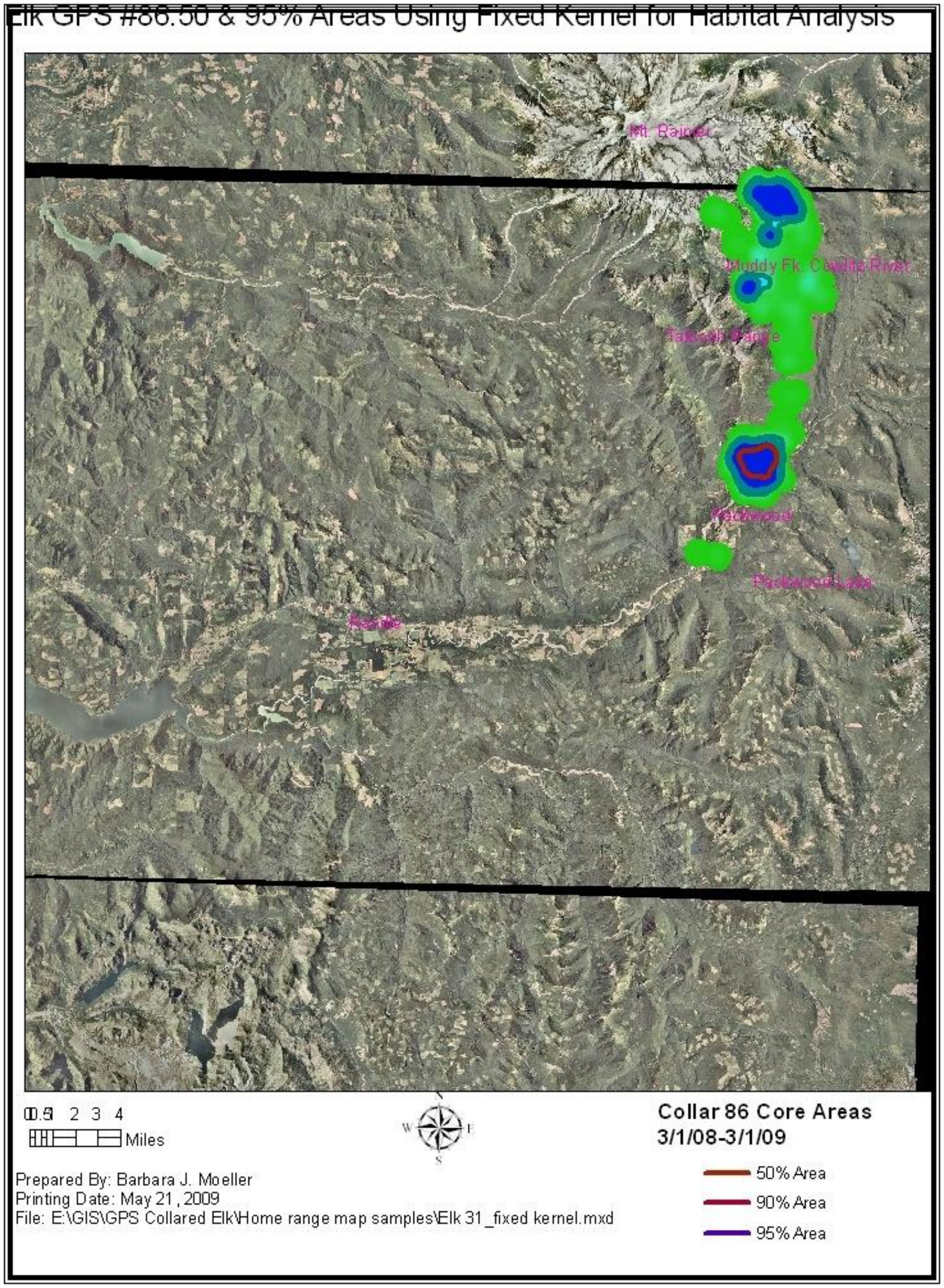
Appendix 3. Collar 84 Batch fixed kernel density at the 50, 90 &95% range areas



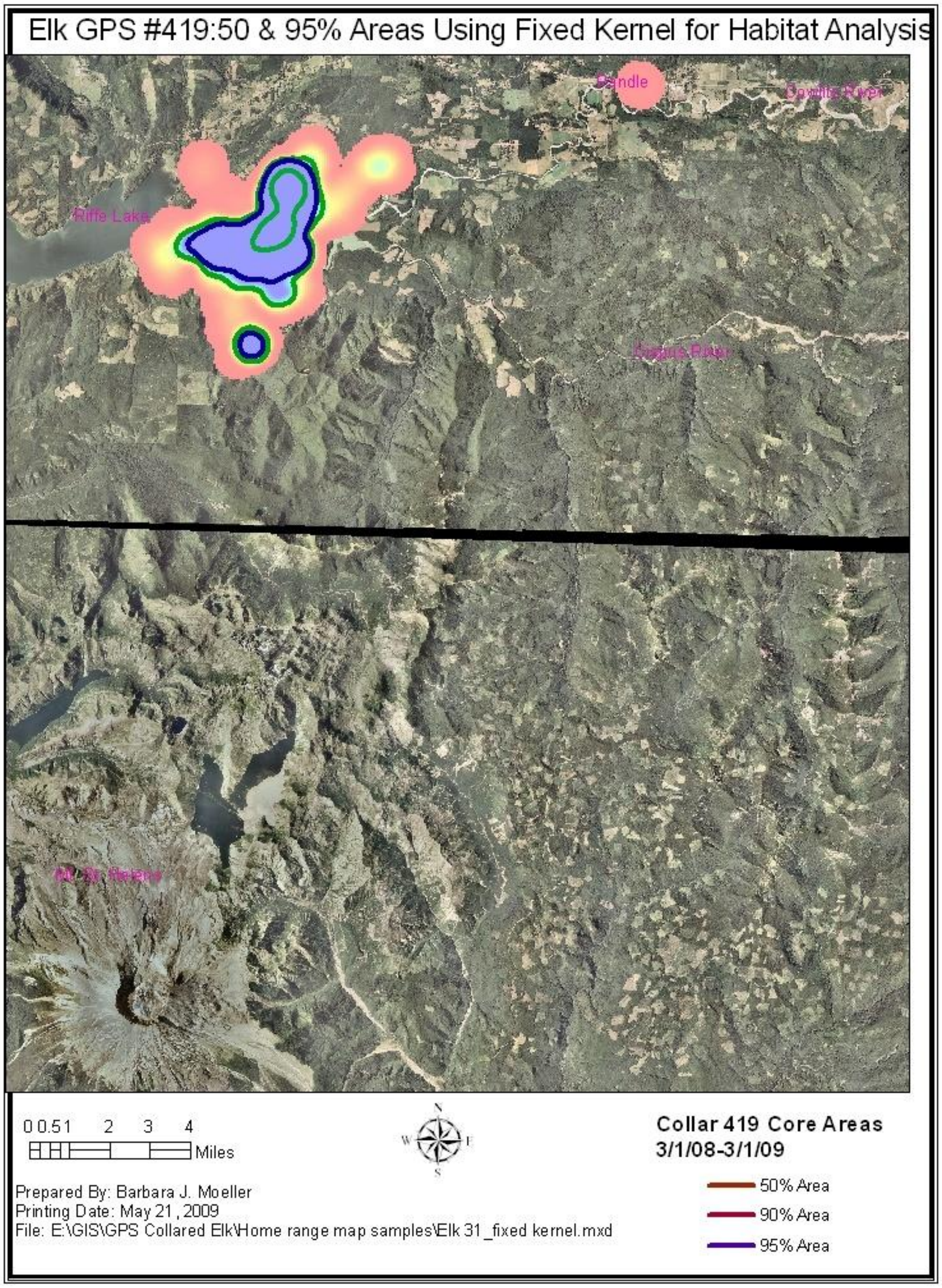
Appendix 3. Collar 85 Batch fixed kernel density at the 50, 90 &95% range areas



Appendix 3. Collar 86 Batch fixed kernel density at the 50, 90 &95% range areas



Appendix 3. Collar 419 Batch fixed kernel density at the 50 & 95% range areas



Appendix 4. Habitat Attributes and distance classes for habitat use analysis of female elk in southwest Washington.

Habitat Attribute	Distance (m) Class
Water	0 – 50
	51-100
	101-200
	201-400
	401-600
	>600
Trails	0 – 100
	101 – 200
	201-400
	400-600
	>600
Non-paved Road	0 – 100
	101-200
	201 – 400
	400-600
	>600
Paved Roads	0 – 600
	>600
Cover	0 – 50
	51-100
	101-200
	201-400
	401-600
	>600
Shrub/scrub	0-50
	51-100
	101-200
	201-400
	401-600
	>600
Slope	0-1 = 1
	1-15=2
	15-30=3
	30-45=4
	45-25000=5

Habitat Attribute	Distance (m) Class
Aspect	-1-0=1 0-90=2 (NE) 90-180=3(SE) 180-270=4(SW) 270-360=5(NW)
Activity	0-10=1 10.1-100=2

Appendix 5. All Elk. Radio frequencies, capture dates and total number of locations of radio-collared elk in southwest Washington, 2004-2008.

Name	Capture Date	# of Locations
Alma	March 2005	61
Amelia	March 2006	39
Andrea	March 2007	25
Anise	March 2008	6689
Annie	March 2006	42
Arnica	March 2008	6627
Becky	March 2005	11
Carrie	March 2005	51
Cheyenne	March 2007	30
Christine	March 2006	10
Cindy	March 2005	64
Cinnamon	March 2008	6890
Clove	March 2008	6793
Cynthia	March 2005	49
Echinacia	March 2008	6720
Eleanor	March 2006	42
Erika	March 2005	49
Hilary	March 2006	11
Jane	March 2006	28
Kate	March 2005	62
Kathie	March 2005	42
Kendra	March 2007	6177
Liz	March 2005	61
Marilu	March 2005	47
Mary	March 2005	64
Mary Ellen	March 2007	5471
Nevada	March 2006	42
Nutmeg	March 2008	6482
Roslyns	March 2007	4873
Sage	March 2008	6876
Sally	March 2005	63
Sheila	March 2005	63
Susan	March 2005	46
Therese	March 2006	42

Appendix 6. Elk name, life home range area, and migratory status of radio-collared elk in southwest Washington, 2004-2008.

Name	MCP Area Km^2	Migratory Status
Akirst	45.57	Non-migratory
Bridget	25.62	Non-migratory
Elma	19.35	Non-migratory
Gertrude	7.66	Non-migratory
Heather	25.88	Non-migratory
Janie	5.69	Non-migratory
Jennifer	10.09	Non-migratory
Judee	12.48	Non-migratory
Judy	19.53	Non-migratory
Lavender	5.63	Non-migratory
Martina	17.85	Non-migratory
Nicky	21.39	Non-migratory
Pilar	11.44	Non-migratory
Rachel	9.42	Non-migratory
Rosa	79.52	Non-migratory
Ruth	19.78	Non-migratory
Thyme	16.72	Non-migratory
Alison	1.80	Non-migratory
Alma	122.02	Migratory
Amelia	103.45	Migratory
Andrea	125.86	Migratory
Anise	92.22	Migratory
Annie	275.10	Migratory
Arnica	31.45	Migratory
Becky	20.67	Migratory
Carrie	106.21	Migratory
Cheyenne	37.06	Migratory
Christine	57.61	Migratory
Cindy	221.87	Migratory
Cinnamon	45.52	Migratory
Clove	42.70	Migratory
Cynthia	137.69	Migratory
Echinacia	177.79	Migratory

Name	MCP Area Km^2	Migratory Status
Eleanor	109.34	Migratory
Erika	66.22	Migratory
Jane	61.05	Migratory
Kate	118.72	Migratory
Kathie	107.25	Migratory
Kaye	270.84	Migratory
Kendra	48.03	Migratory
Liz	113.34	Migratory
Marilu	99.32	Migratory
Mary	95.72	Migratory
MaryEllen	83.37	Migratory
Nevada	76.36	Migratory
Nutmeg	79.47	Migratory
Roslyn	96.62	Migratory
Sage	70.20	Migratory
Sally	76.40	Migratory
Sheila	73.44	Migratory
Susan	82.96	Migratory
Therese	96.60	Migratory
Bettina	198.73	Migratory

Appendix 7. Habitat use of aspects by elk in the combined Randle and Packwood study areas at the 50% and 95% range scales in the Southwest Cascades of Washington. 2007-2008.

Migratory Elk								
Aspect	Winter 50%	Winter 50%	Spring 50%	Spring 50%	Summer 50%	Summer 50%	Fall 50%	Fall 50%
Flat	10%	10%	10%	10%	11%	11%	13%	13%
NE	16%	42%	15%	42%	17%	40%	20%	36%
SE	32%	48%	32%	48%	34%	49%	36%	50%
SW	16%		16%		16%		15%	
NW	26%		27%		23%		17%	

Non-migratory Elk								
Aspect	Winter 50%	Winter 50%	Spring 50%	Spring 50%	Summer 50%	Summer 50%	Fall 50%	Fall 50%
Flat	19%	19%	17%	17%	21%	21%	15%	15%
NE	11%	29%	10%	32%	12%	26%	9%	36%
SE	24%	52%	22%	51%	25%	53%	21%	50%
SW	28%		29%		28%		29%	
NW	18%		22%		14%		27%	

Migratory Elk								
Aspect	Winter 95%	Winter 95%	Spring 95%	Spring 95%	Summer 95%	Summer 95%	Fall 95%	Fall 95%
Flat	7%	7%	7%	7%	8%	8%	8%	8%
NE	17%	42%	17%	41%	19%	29%	19%	39%
SE	30%	50%	30%	50%	32%	52%	32%	52%
SW	20%		20%		20%		20%	
NW	25%		24%		20%		20%	

Non-migratory Elk								
Aspect	Winter 95%	Winter 95%	Spring 95%	Spring 95%	Summer 95%	Summer 95%	Fall 95%	Fall 95%
Flat	17%	17%	12%	12%	14%	14%	14%	14%
NE	14%	33%	10%	42%	12%	38%	12%	38%
SE	25%	50%	21%	46%	23%	49%	23%	49%
SW	25%		25%		26%		26%	
NW	19%		32%		26%		26%	

Appendix 8. Habitat use by elk relative to distance to cover in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
Distance to Cover	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category
0-50	57%	47%	36%	43%	61%	52%	49%	61%
50-100	16%	17%	17%	18%	15%	17%	17%	15%
100-200	18%	23%	28%	25%	16%	20%	22%	16%
200-400	7%	10%	14%	11%	7%	9%	10%	7%
400-600	1%	2%	3%	3%	1%	2%	2%	1%
>600	0.00	0.00	0%	0%	0%	0%	0%	0%

Non-migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
Distance to Cover	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category
0-50	34%	44%	33%	35%	39%	51%	46%	53%
50-100	25%	24%	24%	25%	22%	21%	21%	20%
100-200	33%	26%	26%	32%	29%	22%	25%	21%
200-400	9%	6%	6%	8%	10%	6%	7%	6%
400-600	0.00	0.00	0.00	0%	0%	0%	0%	0%
>600	0.00	0.00	0.00	0%	0%	0%	0%	0%

Appendix 9. Habitat use by elk relative to distance to shrub/scrub in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
	% in	% in	% in	% in	% in	% in	% in	% in
Distance to Shrub scrub	Category	Category	Category	Category	Category	Category	Category	Category
0-50	59%	65%	88%	63%	52%	61%	83%	52%
50-100	11%	10%	4%	10%	11%	10%	5%	11%
100-200	17%	14%	5%	15%	17%	14%	6%	17%
200-400	10%	8%	2%	8%	12%	10%	4%	12%
400-600	2%	2%	0%	2%	4%	3%	1%	4%
>600	1%	1%	0%	1%	4%	3%	1%	4%

Non-migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
	% in	% in	% in	% in	% in	% in	% in	% in
Distance to Shrub scrub	Category	Category	Category	Category	Category	Category	Category	Category
0-50	61%	32%	63%	57%	56%	49%	59%	48%
50-100	10%	14%	10%	11%	12%	13%	11%	13%
100-200	16%	27%	15%	18%	18%	21%	17%	22%
200-400	12%	26%	11%	14%	13%	15%	11%	16%
400-600	1%	1%	1%	1%	1%	2%	1%	2%
>600	0%	0%	0%	0%	0%	1%	0%	1%

Appendix 10. Habitat use by elk of slopes in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
% Slope	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category
0-1	14%	11%	1%	5%	11%	10%	1%	3%
1-15	56%	52%	15%	37%	53%	51%	14%	29%
15-30	18%	21%	23%	28%	21%	22%	20%	27%
30-45	8%	10%	26%	17%	10%	11%	27%	22%
45-25000	4%	6%	34%	13%	6%	7%	38%	19%

Non-migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
% Slope	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category
0-1	16%	27%	22%	10%	14%	18%	14%	8%
1-15	62%	61%	62%	56%	63%	63%	63%	56%
15-30	11%	7%	8%	16%	14%	11%	14%	20%
30-45	8%	4%	6%	13%	7%	5%	7%	11%
45-25000	3%	1%	2%	5%	3%	2%	3%	5%

Appendix 11. Habitat use by elk relative to distance to water in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
	% in	% in	% in	% in	% in	% in	% in	% in
Distance to Water	Category	Category	Category	Category	Category	Category	Category	Category
0-50	14%	13%	3%	14%	14%	14%	4%	10%
50-100	13%	12%	4%	13%	12%	13%	5%	9%
100-200	25%	24%	11%	25%	23%	24%	13%	20%
200-400	27%	28%	25%	27%	26%	26%	25%	28%
400-600	13%	14%	28%	14%	13%	13%	22%	17%
>600	1%	1%	28%	1%	11%	11%	31%	16%

Non-migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
	% in	% in	% in	% in	% in	% in	% in	% in
Distance to Water	Category	Category	Category	Category	Category	Category	Category	Category
0-50	10%	17%	8%	12%	13%	13%	10%	14%
50-100	8%	12%	7%	9%	10%	10%	8%	11%
100-200	18%	21%	15%	19%	18%	18%	16%	0.19
200-400	25%	24%	25%	25%	23%	23%	23%	0.23
400-600	13%	10%	14%	12%	13%	13%	14%	12%
>600	26%	32%	32%	23%	24%	24%	29%	22%

Appendix 12. Habitat use by elk relative to distance to paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Spring 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
Distance to Paved Roads								
	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category
0-600	65%	61%	18%	40%	61%	55%	13%	33%
>600	35%	39%	82%	60%	39%	45%	87%	67%

Non-Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Spring 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
Distance to Paved Roads								
	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category	% in Category
0-600	655%	82%	50%	59%	61%	67%	45%	56%
>600	35%	18%	50%	41%	39%	33%	55%	44%

Appendix 13. Habitat use by elk relative to distance to non-paved roads in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
	% in	% in	% in	% in	% in	% in	% in	% in
Distance to Non-paved Roads								
	Category	Category	Category	Category	Category	Category	Category	Category
0-100	7%	8%	4%	10%	0.10	12%	4%	9%
100-200	7%	8%	4%	9%	0.09	10%	4%	9%
200-400	15%	17%	11%	19%	0.16	18%	8%	16%
400-600	20%	21%	15%	23%	0.17	18%	10%	17%
>600	52%	46%	65%	39%	0.49	42%	74%	49%

Non-migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
Distance to Non-paved Roads								
	% in	% in	% in	% in	% in	% in	% in	% in
	Category	Category	Category	Category	Category	Category	Category	Category
0-100	3%	5%	3%	4%	6%	7%	6%	5%
100-200	8%	13%	7%	10%	9%	11%	9%	7%
200-400	24%	34%	21%	28%	23%	26%	24%	19%
400-600	15%	17%	14%	16%	14%	16%	15%	13%
>600	49%	30%	55%	43%	49%	40%	46%	56%

Appendix 14. Habitat use by elk relative to distance to trails in the combined Randle and Packwood study areas at the 50% and 95% range scale in the Southwestern Cascades of Washington, 2007-2008.

Migratory Elk	Winter 50%	Spring 50%	Summer 50%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
	% in	% in	% in	% in	% in	% in	% in	% in
Distance to Trails	Category	Category	Category	Category	Category	Category	Category	Category
0-100	0%	0%	3%	1%	1%	1%	4%	2%
100-200	0%	0%	3%	1%	1%	1%	4%	2%
200-400	0%	0%	9%	5%	2%	3%	9%	5%
400-600	0%	0%	8%	5%	1%	2%	6%	4%
>600	99%	99%	77%	88%	95%	93%	77%	87%

Non-Migratory Elk	Winter 50%	Spring 50%	Summer5 0%	Fall 50%	Winter 95%	Spring 95%	Summer 95%	Fall 95%
	% in	% in	% in	% in	% in	% in	% in	% in
Distance to Trails	0.00	0.00	0.00	0.00	Category	Category	Category	Category
0-100	0.00	0.00	0.00	0.00	0%	0%	0%	0%
100-200	0.00	0.00	0.00	0.00	0%	0%	0%	0%
200-400	0.00	0.00	0.00	0.00	1%	0%	1%	0%
400-600	0.00	0.00	0.00	0.00	1%	0%	1%	0%
>600	0.00	0.00	0.00	0.00	97%	100%	98%	100%

Appendix 15. R^2 values for Individual elk by habitat attribute at both the 50% and 95% scales.

Regression with Nagelkerke Pseudo-R^2 > .2			
		Freq50	Freq95
Habitat Attribute	Collar ID	Pseudo R^2	
Aspect	28M	0.199	
	82M	0.203	
Slope	28M	0.342	0.454
	31M	0.407	0.383
	80M		0.333
	82M	0.266	0.285
	83M	0.665	0.528
	84M	0.568	0.432
	86M		0.32
	419N	0.348	0.205
	421M	0.257	
Cover	28M	0.294	
	421M	0.259	0.366
Non-Paved	28M		0.484
	31M	0.428	0.385
	80M		0.345
	81N	0.207	
	82M	0.737	0.543
	83M	0.208	
	86M		0.411

Regression with Nagelkerke Pseudo-R^2 > .2			
		Freq50	Freq95
Habitat Attribute	Collar ID	Pseudo R^2	
Paved	30M		0.467
	80M		0.341
	82M	0.226	
	83M	0.576	0.477
	84M	0.598	0.527
	86M		0.588
	421M	0.575	0.372
	422M	0.293	0.257
Shrub	80M		0.233
	83M	0.417	0.306
	84M	0.329	0.334
	85N	0.26	
	421M	0.206	0.308
	422M	0.263	0.292
Trail	28M		0.621
	31M		0.299
	84M	0.27	
	419N		0.36
	421M	0.226	
	422M	0.566	0.288
Water	28M		0.352
	83M	0.653	0.484
	421M	0.203	

Appendix 16. GPS collared elk data points per migratory status in the Randle subunit study area.