National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Mount Rainier National Park and Olympic National Park Elk Monitoring Program Annual Report 2015

Natural Resource Data Series NPS/NCCN/NRDS—2016/1041

MUCKLESHOOT INDIAN TRIBE

PUYALLUP TRIBE OF INDIANS

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

ON THIS PAGE
Bull in the North Rainier count unit, Mount Rainier National Park, WA.
Photography by: Muckleshoot Indian Tribe.

ON THE COVER
Elk in the upper Elwha, Olympic National Park, WA.
Photograph by: Patti Happe, Olympic National Park.

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available in digital format from the North Coast and Cascades Network Inventory and Monitoring website (http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Executive Summary

Fiscal year 2015 was the eighth and sixth year of gathering data in Mount Rainier (MORA) and Olympic (OLYM) respectively according to the approved elk monitoring protocol (Griffin et al. 2012 for the North Coast and Cascades Network (NCCN)). Elk monitoring in these large wilderness parks relies on aerial surveys from a helicopter. The number of missed elk during aerial surveys is estimated by applying site-specific models that account for detection bias (Griffin et al. 2012). Summer surveys are intended to provide quantitative estimates of abundance, sex and age composition, and distribution of migratory elk in high elevation trend count areas.

2015 was the hottest year in record in Seattle, and the earliest recorded date of snowmelt at Paradise in MORA over the 8 years that these surveys have been conducted. These climate conditions had an influence on plant phenology (Figure 1) and consequently may have influenced elk use of high elevation meadows and subsequently the elk survey results.

At MORA the South trend count unit was surveyed twice and the North unit was surveyed once. We counted only 280 and 189 elk during the replicate surveys of the South Rainier trend count area, and 297 elk in the North Rainier trend count area. Using the model to correct for detection bias, we estimated that 427 and 319 elk were in the South trend count area, and 408 elk were in the North trend count area at the time of the respective surveys. Estimates of abundance that ranged from 37-69% greater than the raw counts represented the correction for negative detectability biases associated with many of the observed elk groups occurring in small groups under relatively difficult detection conditions (i.e., high concealment of vegetation).

One trend count areas at OLYM - the Core - was surveyed completely. We counted only 72 in the Core. Using the model to correct for detection bias, we estimated that 107 elk were in the Core at the time of the surveys (i.e., a 49% upward adjustment due to detection biases). Additional flights scheduled for OLYM were canceled due to the abnormally low numbers of elk seen in the survey frame in the Core.

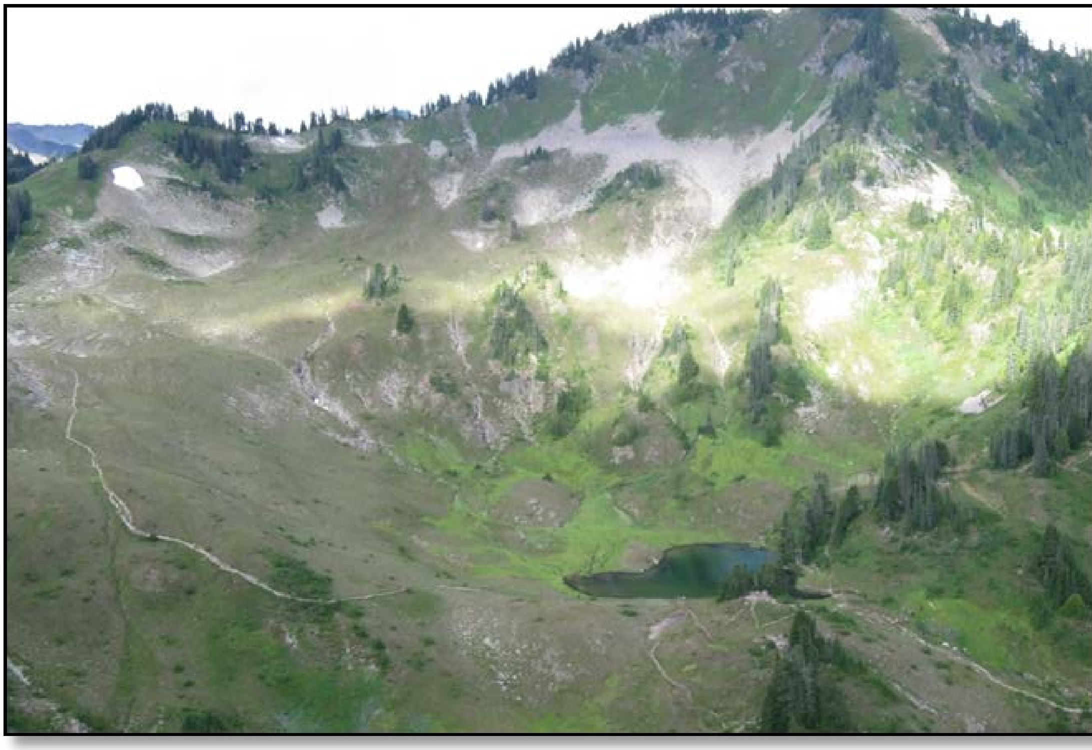

Figure 1. Plant phenology and snowmelt in Heart Lake, Olympic National Park in a) 2008 and b) 2015. The picture in 2008 was taken on 3 September, when there still was a residual snow patch, sedge meadows near the lake were green, and ericaceous low shrubs on the slopes were starting to turn. As early as 19 August in 2015 there was no residual snow, the sedge was turning yellow, and the ericaceous shrubs were either red or senesced (brown).

Acknowledgments

Elk monitoring in MORA and OLYM is a component of the NCCN Inventory and Monitoring (I&M) Program (Weber et al. 2009). Due to ongoing reduced budgets, the program in FY2015 received partial direct funding from the NCCN I&M program. Flights in OLYM were also paid for by the Washington's National Park Fund; in MORA funding was provided by the Washington's National Park Fund, Muckleshoot Indian Tribe (MIT), Puyallup Tribe of Indians (PTOI), and Washington Department of Fish and Wildlife (WDFW), and the NCCN. Additional staff time and data management support was provided by the NCCN I&M program, MORA, OLYM, and U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center (USGS-FRESC). The National Park Service (NPS) is grateful to the MIT, PTOI, and WDFW for their long-standing support for elk monitoring in Mount Rainier National Park, and for being full partners in the development and implementation of the monitoring protocol. Each of these partners contributed substantial funding and personnel in support of aerial surveys, as well as experience and ideas critical to developing and testing the protocol for elk monitoring in these parks. We would like to thank P. Griffin and K. Jenkins (USGS-FRESC) for their role in working with all the partners to develop the elk monitoring protocol for the surveys reported here, and B. Lubow (Colorado State University) for developing the double-observer sightability model. The authors thank the other crew members who participated in surveys including B. Baccus, R. Lofgren, J. Sherwood, L. Perez (NPS); M. Middleton, M. McDaniel Rodarte (MIT); D. Coats, P. Dillon (PTOI); N. Stephen, S. Bergh (WDFW). We thank the following pilots for their assistance and safe flying: R. Olmstead, J. Hagerman (Northwest Helicopters) and Zaron Welch and Jon Bourke (Helicopter Express), and Glenn Kessler, MORA aviation manager. For their support of the elk monitoring program, we thank Muckleshoot Indian Tribe (MIT) Wildlife Committee, and P. Dillon (PTOI). We are grateful to Kurt Jenkins and Jason Ransom for reviews of the draft report.

We also wish to welcome a new member to the elk monitoring team – Tara Chestnut. Tara is the elk monitoring lead for MORA.

Figure 2. Elk in the Southeast count unit, captured at 2000 feet elevation on a fisher project camera, Olympic National Park 2015.

Introduction

Elk populations are key components of lowland and montane ecosystems in MORA and OLYM, and are tightly woven into each park's historical and cultural fabrics. Historical accounts indicate Roosevelt elk (*Cervus elaphus roosevelti*), the Pacific coastal subspecies of elk, were abundant in primeval floodplains and riparian forests along many of the major river systems in western Washington. During summer many herds migrated to subalpine meadows of adjoining mountain chains (Schwartz and Mitchell 1945, Starkey et al. 1982, Taber and Raedeke 1980). Although the ethnographic record clearly indicates that elk were hunted by Native Americans and are indigenous to both the Olympic and Cascades Ranges, early distribution patterns of elk in the Cascades are poorly understood. It is widely acknowledged that elk had become quite rare or absent around Mount Rainier in early historical times for reasons that are not known (Gustafson 1983, Schullery 1983). By the start of the 20th century, unregulated market hunting of elk for meat, antlers, and trophy 'ivory' teeth had widely decimated elk populations throughout the most accessible and settled areas of Oregon and Washington (Graf 1955, Murie 1951). A notable exception was on the Olympic Peninsula where a largely inaccessible wilderness helped to protect a remnant stronghold of native Roosevelt elk.

Elk in Mount Rainier National Park

MORA was created in 1899 to preserve natural wonders of the volcano (Mount Rainier) and its surroundings, and to protect fish and game. Because the park was established largely to protect the mountain, it encompasses mostly montane forests and high elevation subalpine and alpine environments used by elk as summer ranges, but not the majority of low-elevation winter ranges in the adjoining river valleys. Although the native elk had been largely, if not completely eliminated from MORA by 1899, elk populations were reestablished through several translocations of Rocky Mountain elk (*Cervus elaphus nelsoni*) from Yellowstone and Grand Teton National Parks to lands adjacent to the park in 1912-1915 and 1932-1933 (Bradley 1982). Wildlife observation cards maintained at MORA and summarized by Bradley (1982) indicated that by 1915 elk were observed in Grand Park (i.e., the northern part of MORA) just a couple of years following the first releases, and that by the 1930's they had dispersed widely to inhabit the primary summer ranges used by elk today.

From 1950 to the 1970's intensive logging of elk winter ranges adjoining MORA improved winter and spring foraging conditions for elk and stimulated population growth of migratory elk herds that wintered adjacent to the park and summered within (Raedeke and Lehmkuhl 1985, Jenkins and Starkey 1996). In 1962, a U.S. Forest Service biologist counted 466 elk on subalpine meadows within MORA, prompting initial concerns over the potential impacts of elk on subalpine meadows, one of the park's premier natural resources. As elk populations continued to grow during the 1970's and signs of trailing, trampling, and grazing impacts drew greater attention, the following questions assumed primary importance to park managers (Starkey 1984): (1) are the elk native to the park; (2) is the elk population growth a natural ecological process; (3) what changes can be expected into the future; and (4) are the elk having lasting impacts on subalpine vegetation? As a direct response to these growing management concerns, the NPS and several university research cooperators conducted studies of elk history and ethnography in the Mount Rainier ecosystem (Bradley 1982, Gustafson 1983, Schullery 1983), elk distribution and ecology (Bradley 1982, Cooper 1987), elk taxonomy (Schonewald-Cox 1983), land-use and forest succession on winter range (Jenkins and Starkey 1996), and grazing and trampling impacts on subalpine summer ranges (Bradley 1982, Ripple et al. 1988, Motazedian and Sharrow 1984, Sharrow and Kuntz 1986). Primary conclusions of this collective work were that elk were native to the area (Gustafson 1983), and that subspecific differences in the Rocky Mountain elk that were reintroduced near the park were not sufficiently distinctive to consider the present population non-native or exotic (Schonewald-Cox 1993, Starkey 1984). It was concluded that elk populations using the park during summer are influenced by logging practices on adjoining winter ranges, but that post-logging forest succession patterns had reduced forage availability on the winter range and ameliorated population growth trends by the late 1980's (Jenkins and Starkey 1996). Although trailing and trampling impacts were locally important (Bradley 1982, Ripple et al. 1988), grazing impacts were not clearly demonstrated (Sharrow and Kuntz 1986). Because elk are such important drivers of ecosystem change, however, it was suggested that long-term monitoring of both subalpine vegetation and elk populations should be sustained indefinitely (Starkey 1984). Elk monitoring in MORA has continued from 1974 to present day.

Elk in Olympic National Park

OLYM was created first as Mount Olympus National Monument in 1909 by Theodore Roosevelt for the explicit purpose of protecting the last stronghold of Roosevelt elk and its native forested habitat following the large-scale decline in elk populations. Although elk were very abundant throughout the Olympic Peninsula in early historical times, by the turn of the 20th century only 3,000 remained, primarily in the central core of the Peninsula that is currently OLYM (Morganroth 1909). Mount Olympus National Monument was expanded and re-created as OLYM in 1938 to "provide suitable winter range and permanent protection for herds of native Roosevelt elk" (U.S. Congress 1938). Because elk were central to the creation of the park, its boundaries represent as complete an ecological system as was possible when the park was created, including both subalpine summer ranges of elk in the park's mountainous interior, and the many low-elevation river valleys used as winter range. Today the park is internationally recognized by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as a Biosphere Reserve and a World Heritage Site.

The creation of Mt. Olympus National Monument was just one of several coordinated measures to protect dwindling elk herds throughout Washington in the early 1900s. In addition to the efforts to restock former big game ranges in other areas of the state (i.e., the Mount Rainier ecosystem), elk were protected through a moratorium on hunting, and through an aggressive campaign against predators. A bounty was placed on wolves and cougars, which reduced predation on elk, and ultimately led to the eradication of wolves on the Olympic Peninsula by the late 1920's (Scheffer 1995).

Elk populations responded favorably to multifaceted protection on the Olympic Peninsula. As early as 1915, there were reports of 'overbrowsing' in the western rainforest valleys of the Mt. Olympus National Monument, and large numbers of elk were reported dying during severe winters (Schwartz 1939). During the 1930's, several U.S. Forest Service and NPS biologists examined elk ranges throughout the park and reported concerns about overgrazing in low-elevation winter ranges within the temperate rainforests (Murie 1935a, Murie 1935b, Sumner 1938, Schwartz 1939). Twenty years later, Newman (1958) noted that the range was not severely over used and that the elk population was stable because of the "rapid and regular seasonal growth of forage plants, even pressure from predators, and natural die-offs".

Elk continue to play an important ecological role in both MORA and OLYM – as architects of plant communities, drivers of ecosystem processes, and sustainers of diverse communities of predators and scavengers. In addition to these important ecological roles in the ecosystem, elk in both parks are significant to hundreds of thousands of visitors annually who travel to these parks with the hope of viewing elk in their natural environment.

Land use, hunting, and predator management programs on lands adjacent to these parks have the potential to influence elk population trends and ecosystem dynamics within the parks. In addition, wolf recolonization and emerging diseases, such as Treponeme Associated Hoof Disease (Mansfield et al. 2011, Han and Mansfield 2014, Wilson-Welder, et. al. 2015), have the potential to significantly influence elk herds if they spread into Park lands. Information on ungulate population trends has important management significance in NCCN parks through its influence on internal park management decisions, and the ability of the NPS to work effectively with land and wildlife managing agencies and local Native American Tribes in establishing common management goals and objectives outside the park's boundaries. Furthermore, interpreting the status, trends, and ecological significance of park resources to an interested public is an important function of the National Park Service.

Monitoring Objectives

There are two specific objectives of the MORA and OLYM elk monitoring protocol.

> **Objective 1**: Monitor trends in elk abundance, distribution, and composition in selected subalpine summer ranges in MORA and OLYM.
>
> **Objective 2:** Monitor trends in elk abundance and distribution in selected low-elevation winter ranges in OLYM.

Previously we had a third objective to monitor trends in counts and spatial distribution of elk in three of the primary low-elevation winter ranges used by elk in OLYM. Due to budgetary constraints, however, we discontinued conducting winter range surveys in OLYM in 2011. Additional winter range surveys will be conducted in the future as funding allows (Griffin et al. 2012).

Survey and Reporting Objectives for 2015

These results of the 2015 elk surveys in MORA and OLYM are for administrative purposes; data are summarized and presented without extensive analysis or interpretation. The elk monitoring protocol (Griffin et al. 2012) calls for providing reports that contain more comprehensive data analysis every four years, including quantified estimates of variance and trends, and interpretation of those data. A 4-year report that examined trends in counts obtained from 2008-2011 was completed in 2014 (Jenkins et al. 2015).

The objectives of this report are to summarize results of elk surveys conducted in selected subalpine summer ranges in MORA and OLYM during summer 2015. The protocol calls for reporting flight conditions, raw counts of elk, and estimates of elk abundance corrected for detection biases. Raw elk counts are adjusted to account for detection biases (the underestimation of numbers of elk actually present) using double-observer sightability models previously developed for use in MORA and OLYM (Griffin et al. 2012, Lubow et al. 2015). The estimation of elk population abundance and composition based on the double-observer sightability models account for difficulties seeing all elk present in the survey areas, particularly small groups of elk in forested cover. Other relatively minor adjustments to the raw data are made based on animal activity, lighting conditions, position of the elk relative to helicopter and pilot experience (Griffin et al. 2013, Lubow et al. 2015).

Due to funding constraints, a decision was made by the partners in the 2014 annual meeting to switch to an every other year monitoring schedule, as per the protocol (Griffin et al. 2012), following the completion of the 2015 surveys and the next synthesis report. The second comprehensive report, using data from 2008-2015, is schedule to be completed in 2016. Surveys are scheduled to resume in 2017.

Because 2015 was the last year of data collection prior to the next syntheses report, and the last year of surveying annually, the partners agreed to increase the survey effort in 2015 in order to have a rich dataset for the analysis. Consequently, the survey objectives in 2015 were to complete two replicate surveys of the summer range of both the North and the South Rainier Herd in MORA. In OLYM the objective was to survey the Core and three alternate trend count areas, leading to two complete counts in the alternate areas and 6 in the Core for use in the synthesis.

Support for the 2015 flights in MORA came from the NCCN, Washington’s National Park Fund, WDFW, MIT, and PTOI, and in OLYM, support came from the NCCN and Washington’s National Park Fund. Due to budgetary constraints, winter range surveys in OLYM were suspended in 2011. Following the monitoring protocol, the winter range surveys in OLYM are treated as a legacy dataset, and additional surveys will be conducted in the future as funding allows (Griffin et al. 2012).

Study Area

In MORA, the two trend count areas include all of the subalpine habitats in the park that are encompassed by an arc around the volcano from Vernal Park in the north, to Chinook Pass at the east, and south through the Tatoosh Range (Figure 3). These trend count areas include the primary subalpine summer ranges of the North Rainier Herd and South Rainier Herd.

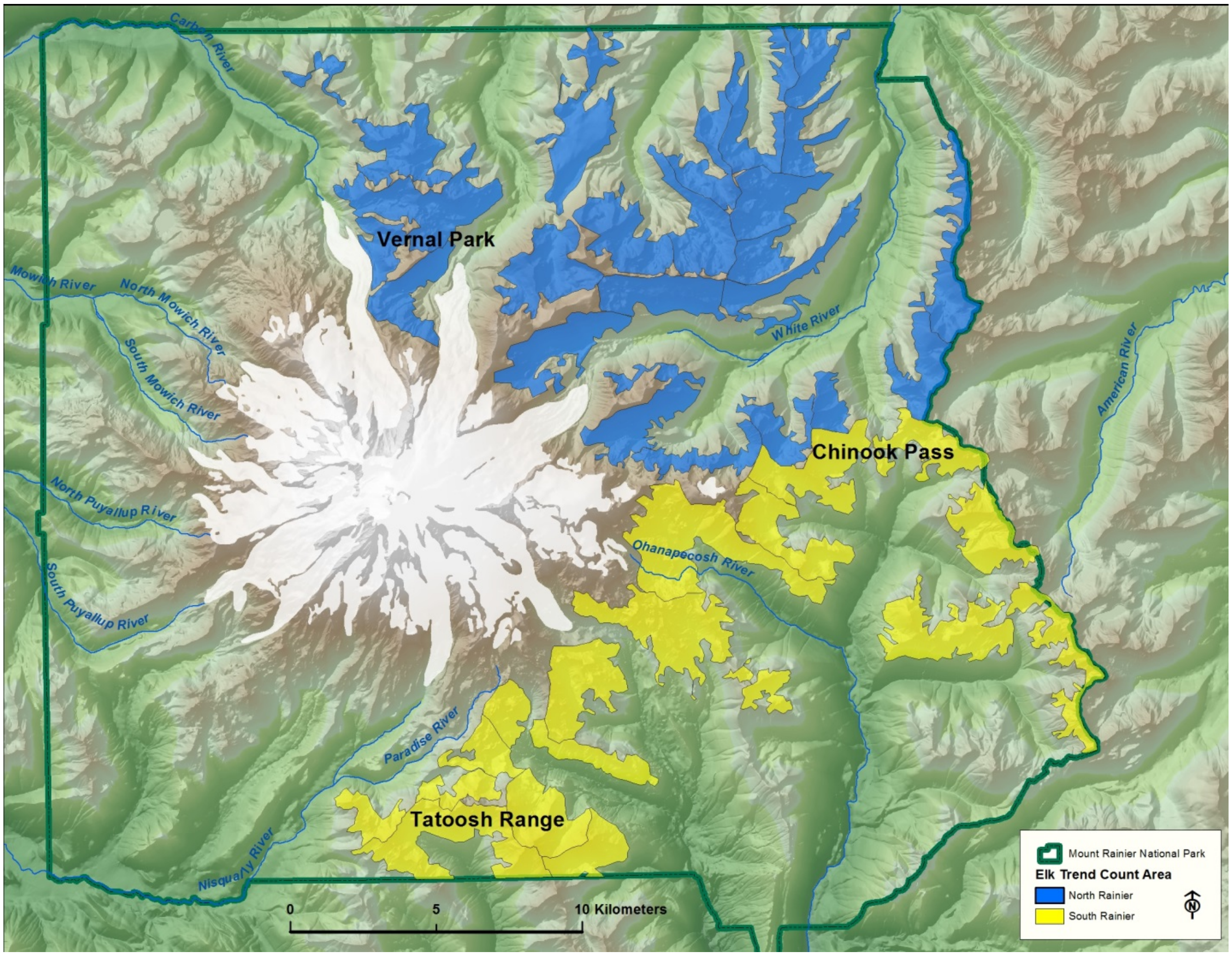

Figure 3. Summer elk trend count areas within Mount Rainier National Park. The North Rainier trend count area is approximately 103 km^2, and the South Rainier trend count area is approximately 89 km^2.

In OLYM the majority of the summer range for migratory elk is divided into five trend count areas. The Core area corresponds with summer range of migratory herds of elk that winter in the primary low-elevation winter ranges in the Hoh and Queets Valleys (Schwartz and Mitchell 1945, Olympic National Park, unpublished data). The four alternate summer range trend count areas (Figure 4) encompass the majority of the remaining migratory elk populations in the Park. Elk in the Quinault, Elwha and Northwest trend count areas winter in OLYM, whereas elk in the Southeast trend count area migrate out of OLYM and winter near the Hood Canal.

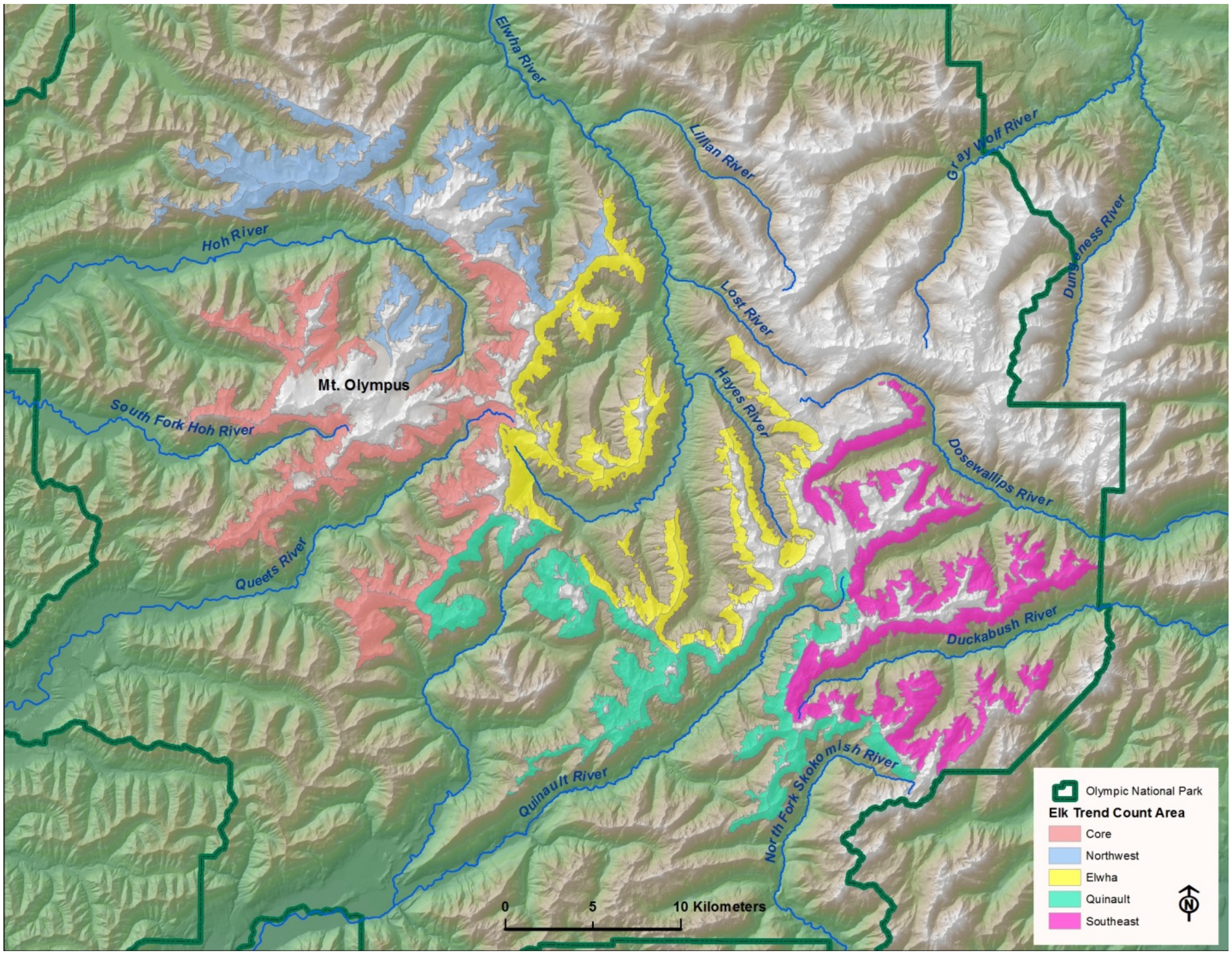

Figure 4. Summer elk trend count areas within Olympic National Park, including the annually-surveyed, Core trend count area, and four ancillary trend count areas surveyed once every four years. The Core and four alternate trend count areas: Elwha, Northwest, Quinault, and Southeast are approximately 100, 81, 73, 79, and 86 km^2, respectively.

Methods

The sample design, survey methods, and analytical framework for elk monitoring are presented in detail in the elk monitoring protocol for MORA and OLYM (Griffin et al. 2012). Salient features are summarized below.

Safety

All helicopter survey operations strictly followed helicopter use aviation safety plans, prepared specifically for each survey.

Sample Design

The summer trend count areas established in MORA (Figure 3) and OLYM (Figure 4) comprise most of the subalpine summer ranges used by elk in each park. We defined trend count areas on the basis of elevation and forest canopy cover. Within the elevation boundaries of trend count areas, we used each park's vegetation cover map (Pacific Meridian Resources 1996) and data gathered during earlier surveys to identify and exclude areas of continuous dense forest canopy cover or rock and snow. In MORA, trend count areas were bounded by elevations below 2100 m and above 1500 m for the North trend count area, and by elevations below 2100 m and above 1350 m for the South Rainier trend count area, except that on the SW facing slopes of Stevens Ridge and Shriner Peak we surveyed down to 1200 m. In OLYM, the majority of the summer trend count areas ranged between 1200 m and 1650 m.

The sampling design calls for completing one replicate survey of both trend count areas in MORA, with an additional replicate of one of the survey areas alternating between years. For example, in 2014 the South was surveyed twice and the North once. Surveys in MORA are conducted in the 4 hours before sunset. In OLYM two trend count areas are surveyed once each year, with the Core area flown each year and one of the other four alternate areas selected on a 4 year rotation. Surveys are flown either 4 hours after sunrise or 4 hours before sunset. All surveys in both parks are to be completed between 15 August and 15 September.

Experience has shown that it is not possible for a single helicopter to effectively survey all of the North Rainier trend count area or all of the South Rainier trend count area in one evening (Griffin et al. 2012). A similar issue exists in OLYM, where it is not always possible to complete a count area in a single morning. Therefore, it has been necessary to either survey a trend count area over two days or to use two helicopters operating simultaneously to complete the surveys. A stated goal of project participants in the MORA surveys is to use two helicopters operating simultaneously, but this is not always possible due to limitations in helicopter availability and crew scheduling.

We have also discovered that for a variety of logistical reasons, it has not always been possible to survey elk in all of the subunits that comprise a single trend count area. Among the logistics problems encountered are: high winds, clouds or fog that develops during a survey, mechanical problems with helicopters, and temporal constraints associated with darkness. For the 4-year synthesis report, missing survey data were imputed (Jenkins et al 2015) for detailed trend analysis. However, for these annual survey reports the missing data are not imputed. In cases where individual survey units were not surveyed, or were incompletely surveyed, we interpreted and reported estimates for trend count areas as minimum estimates and noted the missing units. The missing survey units will be imputed in an upcoming 4-year synthesis report.

Survey Methods

A crew of a pilot and three observers counted elk from a type-III helicopter; helicopters used in 2015 were Bell 206B-3s and an ASTAR-B3. Trend count areas were thoroughly searched for elk from approximately 150 m (500 feet) above ground level, with flight lines approximately 250-500 m apart. We recorded the location, size (i.e., number of elk within a group) and composition (Adult females [cows]:small, medium, and large bulls, and calves) of all elk groups detected, as well as other covariate data used in estimating aerial survey detection bias. In-flight protocols for the double observer method required all observers to act independently in searching for and detecting elk groups. After reconciling which independent observers detected each observed group of elk, all observers collaborated in determining group size, composition and covariates of detected groups. An elk group was defined as one or more elk in close proximity to each other. When possible, large groups were photographed with a high resolution digital camera (Schoenecker et al. 2006) or GoPro video recorder. In addition, all other wildlife species seen on the flights were recorded (Appendix 1, Appendix 2).

Data Management

Following each survey flight the observers immediately reviewed all data forms and corrected any discrepancies. A GIS Specialist downloaded GPS data of helicopter flight lines to the NCCN project workspace on an OLYM computer server. In MORA, the tribal and WDFW biologists provided copies of their completed data forms, the associated GPS files for the helicopter flight path, and any photographs of large elk groups to the project lead. In OLYM the project manager examined the photos and videos after the flights were completed; if inspection of photos led to a revision for group size, composition, location or covariates, then the pertinent photos were annotated and saved, and changes were made to the data forms. No elk group photos were collected in MORA in 2015.

The OLYM and MORA project managers or NCCN staff entered survey data into the elk project database. After data were entered, quality review included verification, which entailed confirming that data in the database were accurate with respect to the field forms. Next, data were checked for consistency, and all data entered were confirmed to be within acceptable bounds.

Data Analysis

We summarized data according to the template provided in Griffin et al. (2012). Results of surveys are presented here without detailed analysis of temporal trends or other environmental variables that influence estimates (which are covered in the 4-year synthesis reports). Counts of elk in MORA and OLYM were adjusted for aerial detection biases using the revised the double-observer sightability model based on the combined set of detection trial data collected in MORA and OLYM since 2008 (Lubow et al. 2015). Climate data used in this report are from Natural Resource Conservation Service Waterhole (Hurricane Ridge, OLYM) and Paradise (MORA) SNOTEL and the National Weather Service Paradise Coop (MORA) stations (Western Regional Climate Center 2016) (National Water and Climate Center 2016); the methods to summarize these data are described in Appendix A.

Results

2015 Climate in Review

Spring and summer weather conditions were very unusual in 2015. An ocean temperature anomaly in the eastern Pacific greatly influenced land temperatures (Bond, et.al, 2015), contributing to one of the warmest winters on record in the Pacific Northwest. Winter and spring temperatures at high elevation weather stations at Hurricane Ridge (OLYM) and Paradise (MORA) were 4.8° and 4.2°F above normal respectively, resulting in the lowest mountain snowpack since records began. Winter snowpack melted from these locations at OLYM and MORA 50 and 43 days earlier than normal, which is in sharp contrast to previous elk survey years (2008 to 2014 Appendix A). The effects of early snowmelt were compounded by continued warmer than normal temperatures during the summer months of June, July and August (JJA). The month of June measured 7.6° and 10.1°F warmer than normal at Hurricane Ridge and Paradise respectively. While not as extreme, the entire summer season (JJA) was 3.7° and 5.4°F above normal at these locations. In addition to being warmer, this time period was also exceptionally dry. June and July precipitation amounts were 34% and 25% of normal at Hurricane Ridge and Paradise respectively. At Hurricane Ridge, only 0.8” of precipitation fell from June 1st to the date of elk surveys. Similarly, at Paradise, 1.1” of precipitation fell. At OLYM, spring and summer moisture levels were so low that a large wildfire ignited and spread through lowland rainforest in the Queets Valley during this time period.

The early snowpack melt, above normal temperatures and reduced precipitation combined noticeably to alter the phenology of subalpine meadows typically used by elk for summer grazing. The early melt moved forward the date of leaf emergence in these meadows while warm dry conditions appeared to accelerate the rate of growth and then ultimately, the timing of senescence. One method for quantifying this effect is by comparing accumulated growing degree-days (AGDD). Higher AGDD values early in the season reflect accelerated plant growth and early availability of food. Higher values late in the season indicate accelerated senescence of these same plant food sources. AGDD values at OLYM were typically in the range of 600 to 800 (median value of 704) during the elk census periods. In 2015, despite bumping forward the date of flights to mid-August, the AGDD value at OLYM had reached 1245 (Appendix A). The departure from normal AGDD values at MORA in 2015 was even larger: in 2015 AGDD value was 1148, compared with a median value of 422 in all other survey years (Appendix A). The advanced phenological condition of subalpine meadows in 2015 was easily observed by the color changes indicating early senescence of shrubs (red/yellow) and grass/sedges (yellow/brown) (Figures 5 and 6).

Figure 5. 2015 was exceptionally hot and dry, and snowmelt and plant phenology was barely within prescription. Late season plant phenology (red hues in subalpine shrubs, yellow sedges) is illustrated by the phenology photo points at Buck Lake (Mount Rainier National Park 8/13/2015) of the left and Fan Lake (Mount Rainier National Part 9/8/2015) on the right. The prominent ring of exposed sediments around Buck Lake's shoreline also reveals the dry summer conditions.

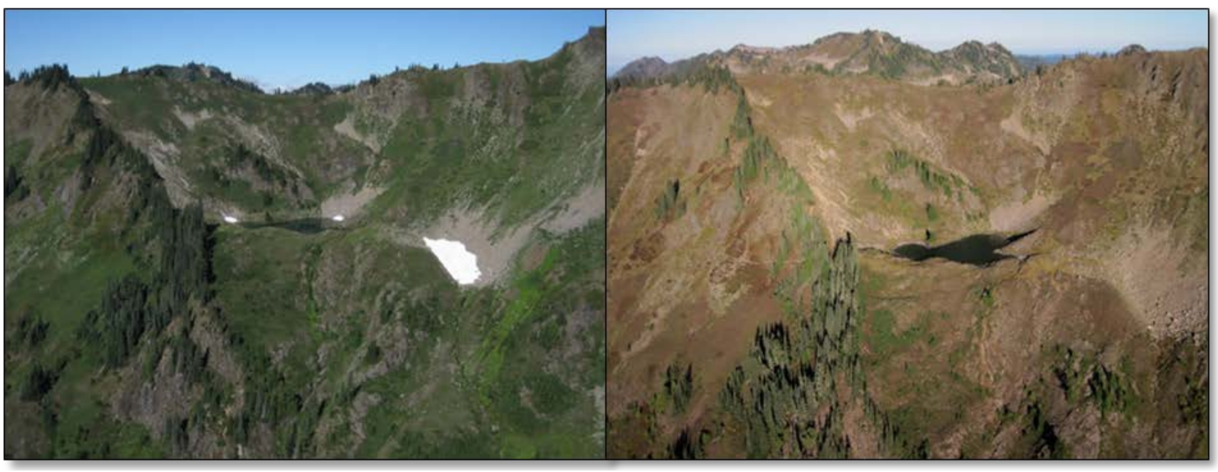

Figure 6. A comparison of phenology photo points highlights the late season conditions of subalpine meadows during the 2015 surveys. On the left, a photo of Swimming Bear Lake (Olympic National Park) during the August 14th 2012 survey (on left), reveals bright green foliage on shrub and sedge meadows as well as remnant snow fields. The same location photographed during the August 17th 2015 survey (right), shows brown and red foliage and a total absence of snow fields. Accumulated growing degree-day values in 2012 were 632 as compared to 1245 in 2015.

Names and Roles of Project Personnel

Patti Happe served as the project lead in this study and also as the project manager for OLYM. Tara Chestnut served as the project manager for MORA. David Vales, lead wildlife biologist for Muckleshoot Indian Tribe (MIT), coordinated the survey conducted by MIT. Barbara Moeller, wildlife biologist for Puyallup Tribe of Indians (PTOI), coordinated the survey conducted by PTOI, whereas Michelle Tirhi and Eric Holman, wildlife biologists for Washington Department of Fish and Wildlife (WDFW) Region 6 and Region 5, respectively, supervised two WDFW surveys. Other survey personnel that took part in spring and summer surveys are listed in Table 1. Two of the pilots, Zaron Welch and Jon Bourke who flew the A-STAR and MORA, were new to the survey.

Table 1. Observers that participated in elk surveys in 2015. Personnel are identified by the tribe or agency with which they are affiliated.

Affiliation	Names
National Park Service	Patti Happe, Kathy Beirne, Bill Baccus, Rebecca Lofgren, Tara Chestnut (survey crew members); Bill Baccus, Katherine Beirne, Jessica Sherwood, Larissa Perez (helicopter managers)
Muckleshoot Indian Tribe	Dave Vales, Mike Middleton, Mike McDaniel,
Puyallup Tribe of Indians	Barbara Moeller, D. Coats, Phillip Dillon
Washington Department of Fish and Wildlife	Stefanie Bergh, Nicholle Stephens, Eric Holman.
Pilots	Rob Olmstead, Jess Hagerman, Zaron Welch, Jon Bourke

Flight Statistics

Mount Rainier Summer Surveys

During 2015, project partners completed two replicate surveys of the South Rainier trend count area and only one replicate survey of the North Rainier trend count area (Table 2). We were unable to conduct a replicate survey of the North Rainier trend count area because weather condition on the days of the scheduled flight and back up date were unsafe to fly, and limited availability of the MORA contract helicopter on other dates.

For all surveys in 2015, we were able to complete the replicate counts of each trend count area on the same day, using 2 helicopters (Table 2). The first replicate survey for the South Rainier trend count area was conducted on 11 August, and the second almost a month later on 8 September. Unit S13 was not flown in the first survey, but was covered in the second. The survey for the North Rainier trend count area was conducted on 13 August under good flat light and temperature (62^{o}F) conditions.

Table 2. Flight details for summer 2015 elk surveys at Mount Rainier National Park. Last names of pilots are indicated in bold font.

Flight	Date	Replicate	Survey Units	Total flight time (h:min)	Survey time (h:min)	Sponsor[1]	Crew Members
1	Aug 11	First South	S8, S10, S11, S14, S15, S16	2:44	2:24	PTIO	Moeller, Dillon, Coats, **Hagerman**
2	Aug 11	First South	S1,S4,S5,S6,S7,S9,S17, S18,S19,S20.	3:41*	2:28	NPS	Beirne, Lofgren, Chestnut, **Welch**
3	Aug 13	First North	N4,N5b,N7,N8,N11,N12,N13,N14	2:30	2:19	MIT	Middleton, McDaniel, Vales,
4	Aug 13	First North	N1,N2,N3,N5a,N6,N9, N10,N15,N16,N17,N18,	2:43	2:31	NPS	Beirne, Lofgren, Chestnut, **Bourke**

Table 2 (continued). Flight details for summer 2015 elk surveys at Mount Rainier National Park. Last names of pilots are indicated in bold font.

Flight	Date	Replicate	Survey Units	Total flight time (h:min)	Survey time (h:min)	Sponsor[1]	Crew Members
5	Sep 8	Second South	S14,S15,S16,S17,S18,S19,S20	**	2:27	WDFW	Bergh, Holman, Stephens, **Hagerman**
6	Sep 8	Second South	S1,S4,S5,S6,S7,S8,S9, S10,S11,S13	2:10	1:55	NPS	Beirne, Lofgren, Chestnut, **Welch**

[1] Sponsors are the Tribe or agencies responsible for funding the helicopter costs. NPS - National Park Service, Mount Rainier National Park, MIT - Muckleshoot Indian Tribe, PTOI - Puyallup Tribe of Indians, WDFW - Washington Department of Fish and Wildlife.

*Flight time includes a break for re-fueling.

**Total flight time was not recorded

Olympic National Park Summer Surveys

We planned to conduct 9 flights over 4 days, and complete surveys in the Core, Quinault, Northwest, and Southeast trend count areas. That schedule would have allowed us make up for time lost capturing elk in 2009 and 2010, and enter into the synthesis report with 6 complete surveys of the Core, and 2 surveys for each of the alternate survey areas (they were supposed to be counted once every 4 survey years as per the protocol).

However we saw unusually low numbers of elk on the first 3 flights (20 elk), and the elk that were seen were in small groups (8 single elk and one group of 12), and predominantly in or near timber and on the lower contours. The hot and dry weather during the winter spring and early summer prior to the survey resulted in very dry conditions on the summer range, as evidenced by the NCCN weather data and illustrated by the phenology photos (Figures 5 and 6). There were no residual snow fields observed in the survey areas, many of the small mountain ponds were dried up, lake levels at high elevations were low, and plants desiccated or senesced (Figures 1 and 6). We suspected that most of the elk were at lower elevations where forage was more succulent and water more available. That speculation is supported by photographs of elk herds captured on cameras set out for the fisher project at lower elevations (Figure 2). Consequently we canceled the remaining flights scheduled for alternate survey areas. For annual comparisons we did complete the flights in the Core and the two count block in the Northwest that are adjacent to the Core.

We had fair to good counting conditions throughout the flights; skies were clear to partly cloudy and temperatures were warm (12-19 C) but within prescription. During all of the morning flights, the sky was clear and visibility partially impaired by glare and high contrast, especially for elk groups that were in forested cover. Counting conditions were much better in the evening flight, when skies were partly overcast.

Table 3. Flight details for summer 2015 elk surveys at Olympic National Park. Last names of pilots are indicated in bold font.

Flight	**Date**	**Survey Start Time**	**Survey Units**	**Total flight time** (h:min)	**Survey time** (h:min)	**Crew Members**
1	Aug 17	16:43	Q1a,Q1b, C7, C6d (part)	1:49	1:12	Baccus, Beirne, Happe, **Olmstead**
2	Aug 18	06:07	C6d (rest),C6a,C6b,C6c	1:47	1:14	Baccus, Beirne, Happe, **Olmstead**
3	Aug 18	08:12	C3,C4,C5	1:49	1:16	Baccus, Beirne, Happe, **Olmstead**
4	Aug 19	06:06	C1,C2,NW5c	1:50	1:22	Baccus, Beirne, Happe, **Olmstead**
5	Aug 19	08:18	NW1	0:46	0:30	Baccus, Beirne, Happe, **Olmstead**

Elk Observations

Mount Rainier Summer Surveys

Survey paths (flight lines) flown during the summer surveys in MORA are illustrated in figures 7 through 9. On the first replicate count of the South herd unit S13 was missed (Figure 7). All units were completed in subsequent counts.

Observed groups of elk in MORA are summarized in Tables 4 and 6. We saw 309 elk in 58 groups in the first South trend count area replicate count and only 209 elk in 59 groups on the second replicate. The mean group size and maximum group size were greater in the first count, 5.4 and 40 elk respectively, than in the second, where the largest group seen was only 13 elk. In the North trend count area, 336 elk were observed in 48 groups; the average group size was 7.1 elk and the largest group seen contained only 32 elk

Of note, 31 elk in 8 groups were seen below the survey area in or below the 300m buffer on the first South Rainier replicate, and 20 elk in 5 groups were below the count unit in the second replicate. Similarly, in the North trend count area, 9 elk in 6 groups were below the survey count area. (Data from elk groups seen below the count area in the 300m buffer are not used for population trend analysis, but are used in estimate herd composition.)

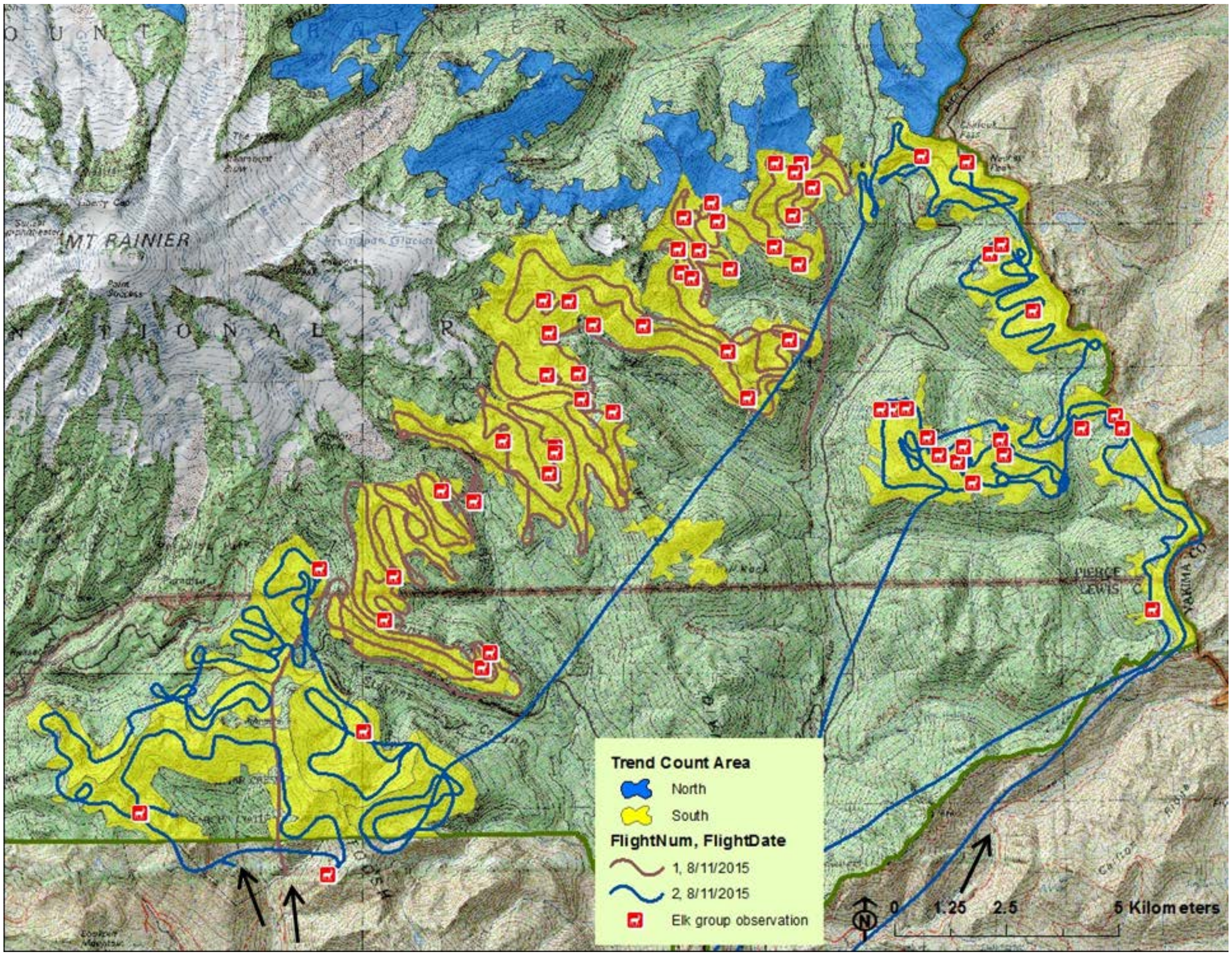

Figure 7. Flight lines (brown=flight 1, blue=flight 2) for the first survey in the South Rainier elk trend count area, conducted 11 August 2015. Both flights originated and ended south of the survey area; black arrows indicate the start point and the flight path direction for each flight line. There was one re-fueling during flight 2. Approximate locations of observed elk groups are indicated with the red icon.

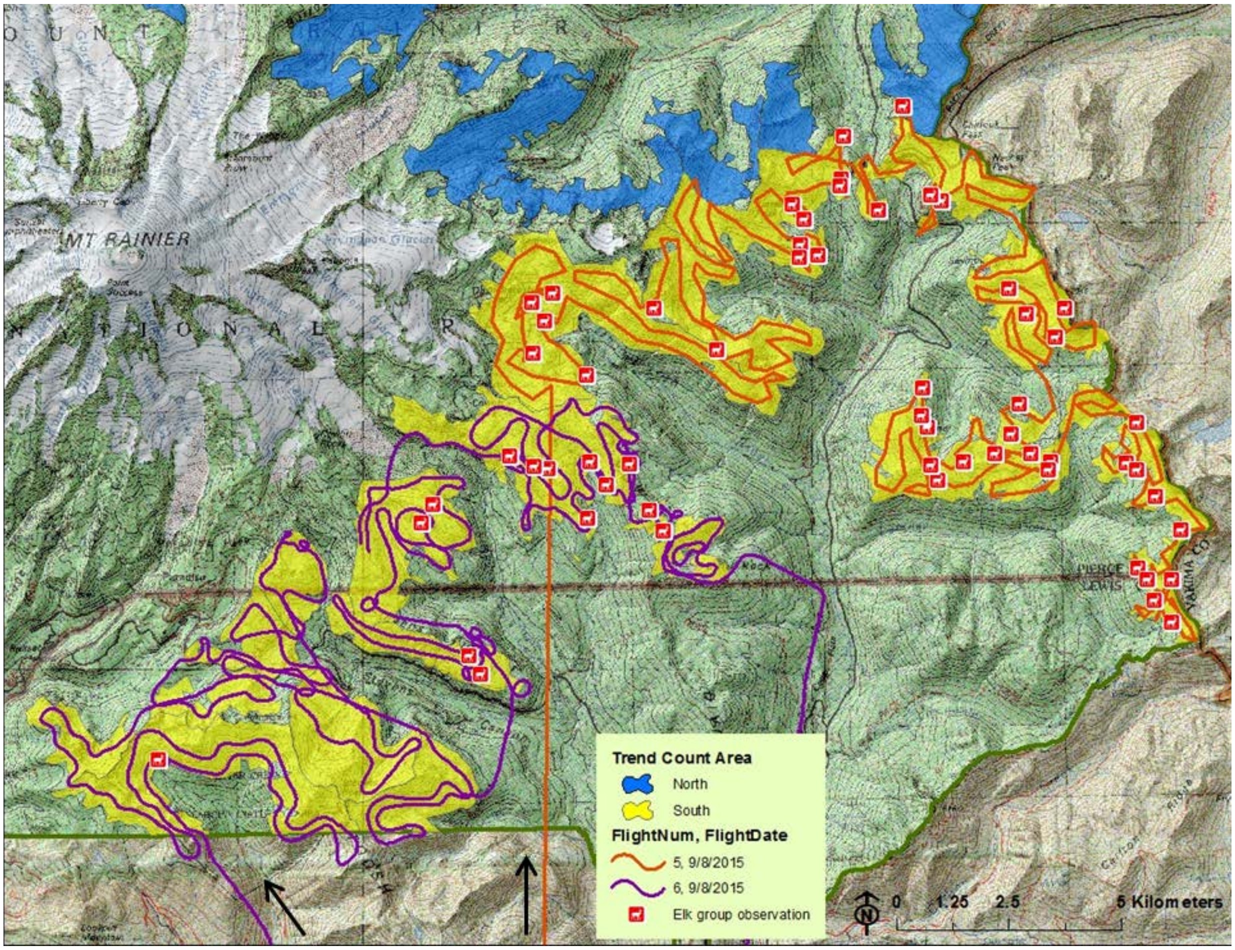

Figure 8. Flight lines (orange=flight 5, purple=flight 6) for the second replicate survey in the South Rainier elk trend count area, conducted 8 September 2015. All flights originated and ended south of the survey area; black arrows indicate the start point and the flight path direction for each flight line. Approximate locations of observed elk groups are indicated with the red icon.

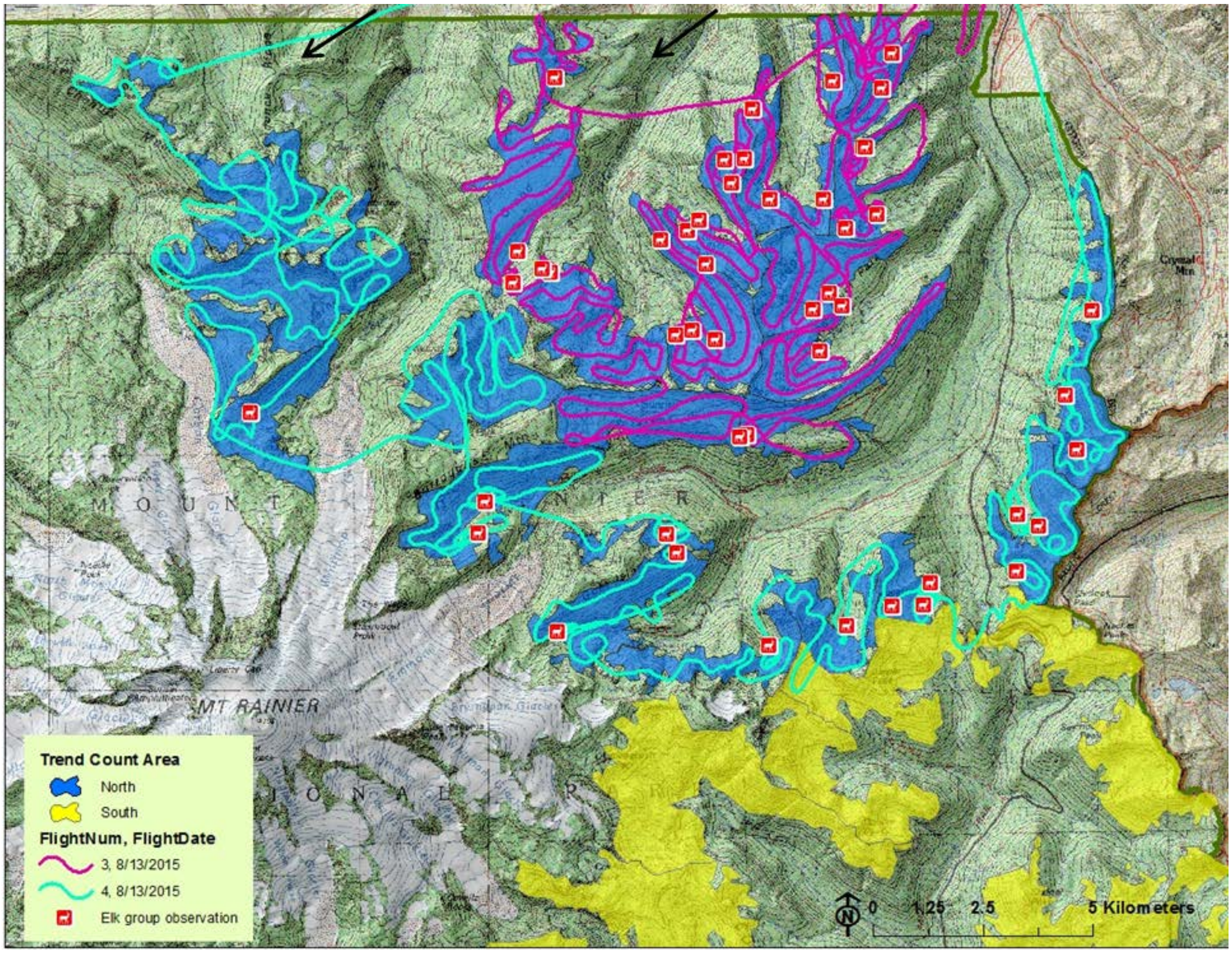

Figure 9. Flight lines (pink=flight 3, aqua=flight 4) for the survey in the North Rainier elk trend count area, conducted 13 August 2015. All flights originated and ended north of the survey area; black arrows indicate the start point and the flight path direction for each flight line. Observed elk groups are indicated with the red icons.

Table 4. Summarized elk observations from two replicate surveys of the South Rainier trend count area, and one survey of the North Rainier trend count area. Counts include elk seen in the counts of each survey unit and a 300m buffer around each unit.

Trend Count Area	Groups	Total Elk[1]	Cows	Calves	Bulls			Calves per 100 Cows	Bulls per 100 Cows	Mean Group Size	Max. Group Size
					Spike	Sub-adult	Mature				
South Rainier (Rep.1)	58	309	185	69	5	9	37	37.30	27.57	5.4	40
South Rainier (Rep. 2)	59	209	114	53	2	17	23	46.49	36.84	3.5	13
North Rainier	48	336	182	81	24	20	29	44.51	40.11	7.1	32

[1] includes unclassified elk.

Olympic National Park Summer Surveys

Figure 10 shows the flight paths and location of elk groups observed during the summer in OLYM in the Core and adjacent units in the Quinault and Northwest trend count areas. Counts and composition of elk groups seen in OLYM surveys are summarized in Table 5. We saw exceptionally low numbers of elk in the Core: only 75 elk in 12 groups. When the elk that were in the buffer are excluded, we ended up with only 72 elk in 9 groups.

We saw only one large group in the count area – a herd of 48 in Ferry Basin. This group represents 68% of the elk seen in the core area. All other elk detected were in small groups or individual elk widely dispersed throughout the count area (Figure 10). The Ferry Basin group was the only group that was seen at higher elevations (4800') in open shrub and herbaceous meadows. It was moving up towards the pass when detected, and on the next flight the group was re-sighted 70 minutes later, 1.6 km away on the other side the ridge in 75 % or greater conifer cover. (Herd group identity was verified via re-sighting on radio-collars).

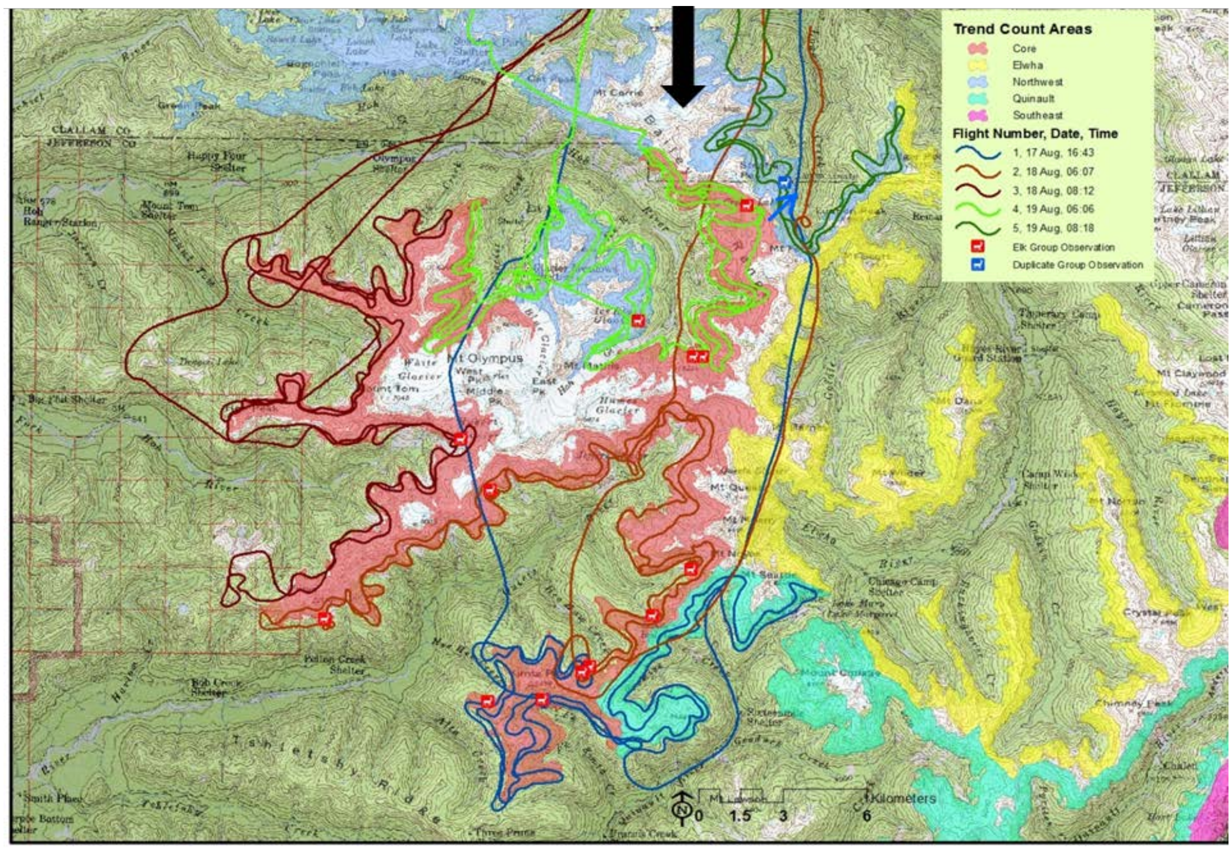

Figure 10. Flight lines in the Core elk trend count area of Olympic National Park conducted 17-19 August 2015. All flights originated and ended north of the survey area. The black arrow indicates the start point and the flight path direction for each flight line. Approximate locations of observed elk groups are indicated with the red icons. A duplicate count of a group that moved between count units on sequential flights is indicated with the blue icon, and direction of elk movement indicated with the blue line.

Table 5. Summarized elk observations from summer surveys in Olympic National Park. Counts include elk seen in the survey unit and a 300m buffer around each unit.

Trend Count Area	Groups	Total Elk[1]	Cows	Calves	Bulls			Calves per 100 Cows	Bulls per 100 Cows	Mean Group Size	Max. Group Size
					Spike	Sub-adult	Mature				
Core	12	75	37	20	4	1	11	54.05	43.24	5.8	48

[1] includes unclassified elk.

Elk Abundance and Composition Estimates

Mount Rainier Summer Surveys

We applied the updated DO-S model to the 2015 MORA survey data (Table 6). After using the model to adjust for sightability, the estimated abundance of elk increased from 37-69% above the raw counts depending on the survey. Estimated ratios of calves: 100 cows decreased 3-12%, whereas estimated ratios of bulls: 100 cows increased 2-28% compared to estimates derived from the raw counts. The adjustment made to the raw counts in deriving the abundance estimates were higher in 2015 than ever previously reported (Jenkins et al., 2015), indicating primarily the effect of many small groups of elk being in relatively dense cover. Upward adjustments of bull: 100 cow ratios is consistent with previous observations than many bull groups are small and difficult to see (Griffin et al. 2013)

Table 6. Raw and estimated numbers of elk and herd composition in the 2015 Mount Rainier National Park summer surveys in the trend count area. Numbers include only elk seen in the count area and exclude those seen in the buffer.

Trend Count Area	Total Elk Seen	Estimated Abundance	Raw Calves per 100 Cows	Estimated Caves per 100 Cows	Raw Bulls per 100 Cows	Estimated Bulls per 100 Cows
South Rainier (Replicate 1)	280	**427**	37.30	**36.15**	27.57	**35.43**
South Rainier (Replicate 2)	189	**320**	46.49	**41.14**	36.84	**37.68**
North Rainier	297	**408**	44.51	**44.32**	40.11	**51.20**

The updated DO-S model was applied to the MORA survey data from 2008 through 2015 (Figures 11-13). Trend analyses of the 2008-2011 survey data is presented in the 4-year synthesis report (Jenkins et al, 2015). Data from the 2012-2015 MORA surveys will be analyzed in an upcoming synthesis report.

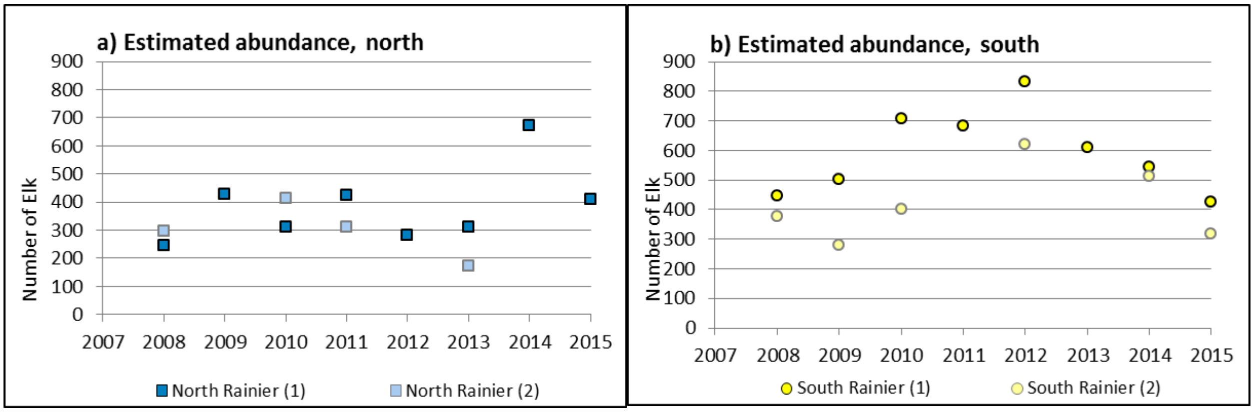

Figure 11. Estimated elk abundance in the a) North Rainier and b) South Rainier herd surveys, 2008-2015.

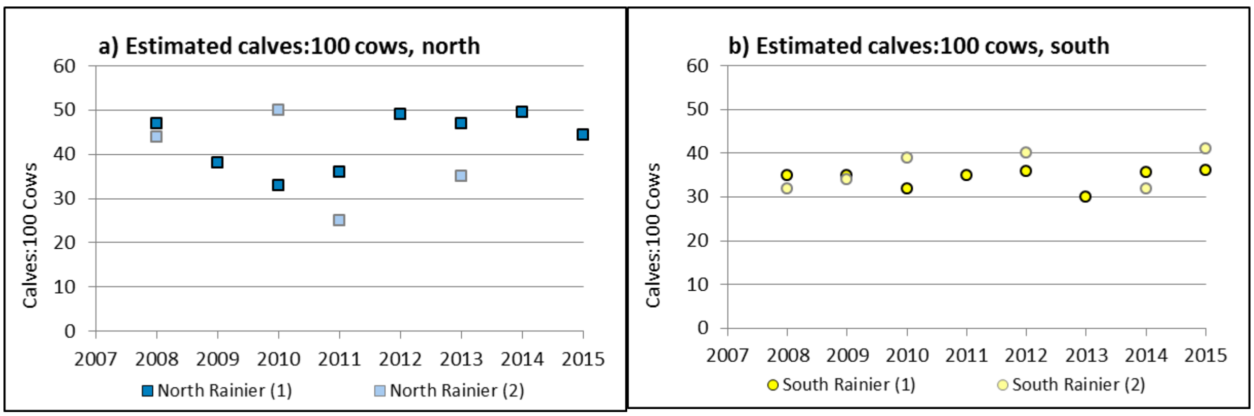

Figure 12. Estimated elk calves: 100 cows in the a) North Rainier and b) South Rainier herd surveys, 2008-2015.

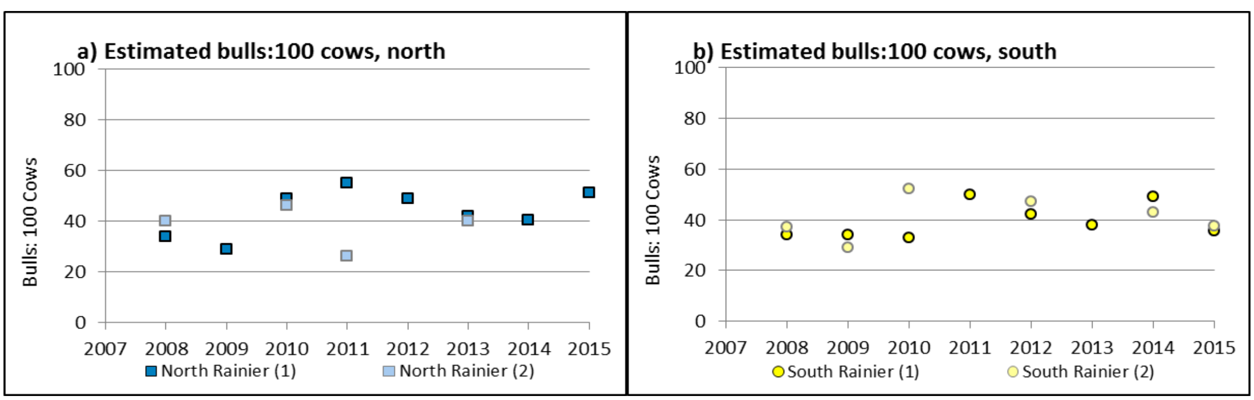

Figure 13. Estimated elk bulls: 100 cows in the a) North Rainier and b) South Rainier herd surveys, 2008-2015.

Olympic Summer Surveys

We applied the double observer sightability model to the 2015 OLYM survey data (Table 7). After using the model to adjust for sightability**,** the low count in the Core was adjusted upwards 49%

compared to the raw count. The estimated ratio of calves: 100 cows increased by only 3% but the bull: cow ratio was adjusted upward by nearly 96%.

Table 7. Raw and estimated numbers of elk and herd composition in the 2015 Olympic National Park summer surveys in the trend count area. Numbers include only elk seen in the count area and exclude those seen in the buffer.

Trend Count Area	Total Elk Seen	Estimated Abundance	Raw Calves per 100 Cows	Estimated Calves per 100 Cows	Raw Bulls per 100 Cows	Estimated Bulls per 100 Cows
Core	72	**107**	54.05	**55.44**	43.24	**84.56**

The updated DO-S model was applied to the OLYM survey data from 2008 through 2015 (Figure 14). Trend analyses of the 2008-2015 survey data in the Core will be analyzed in an upcoming synthesis report.

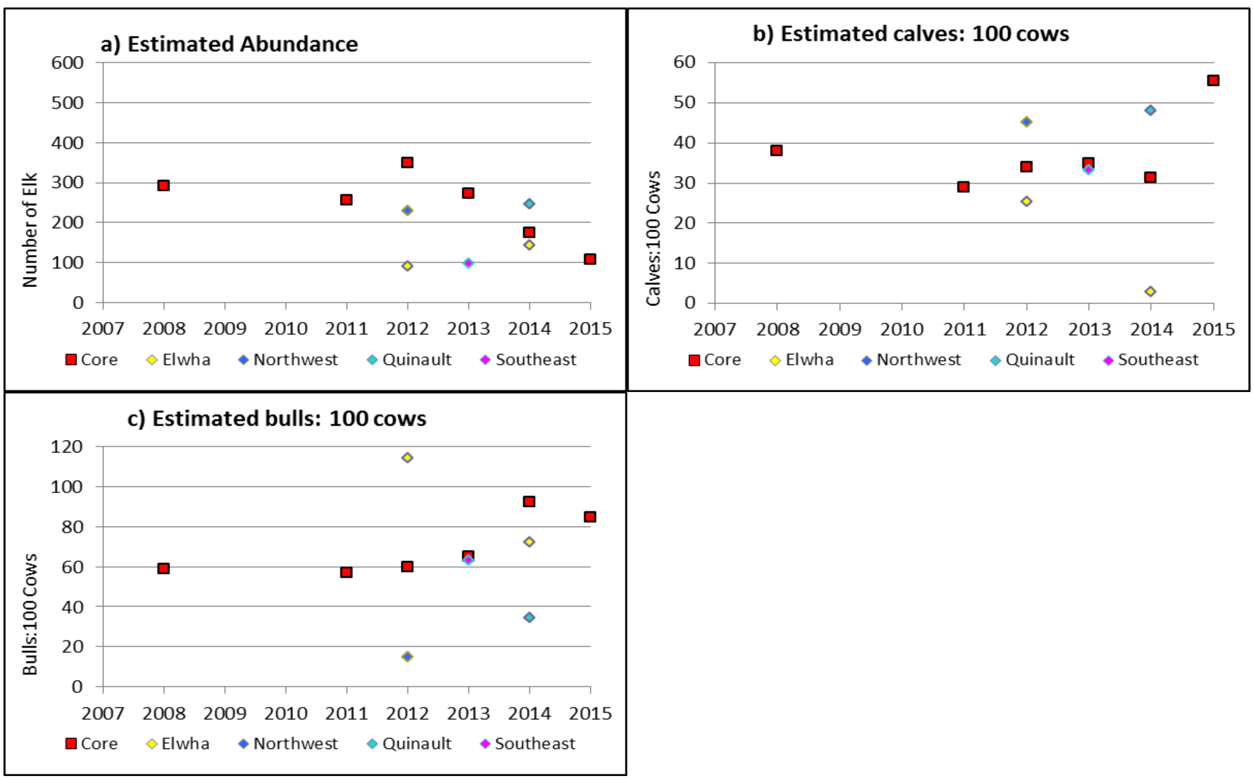

Figure 14. Estimated elk abundance, calves:100 cows and bulls:100 cows in the Core (red), Elwha (yellow), Northwest (blue), Quinault (aqua) and Southeast (pink) trend count areas of Olympic National Park, 2008-2015. No surveys were conducted in 2009 and 2010.

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Appendix A: Climate Conditions in 2015 in Mount Rainier and Olympic National Parks.

In 2015 an ocean temperature anomaly in the eastern Pacific greatly influenced land temperatures (Bond et.al. 2015), contributing to one of the warmest winters on record in the Pacific Northwest. Winter and spring temperatures at high elevation weather stations at Hurricane Ridge (OLYM) and Paradise (MORA) were 4.8° and 4.2°F above normal respectively, resulting in the lowest mountain snowpack since records began. Winter snowpack melted from these locations at OLYM and MORA 50 and 43 days earlier than normal, which is in sharp contrast to previous elk survey years (2008 to 2014) (see Figure A1).

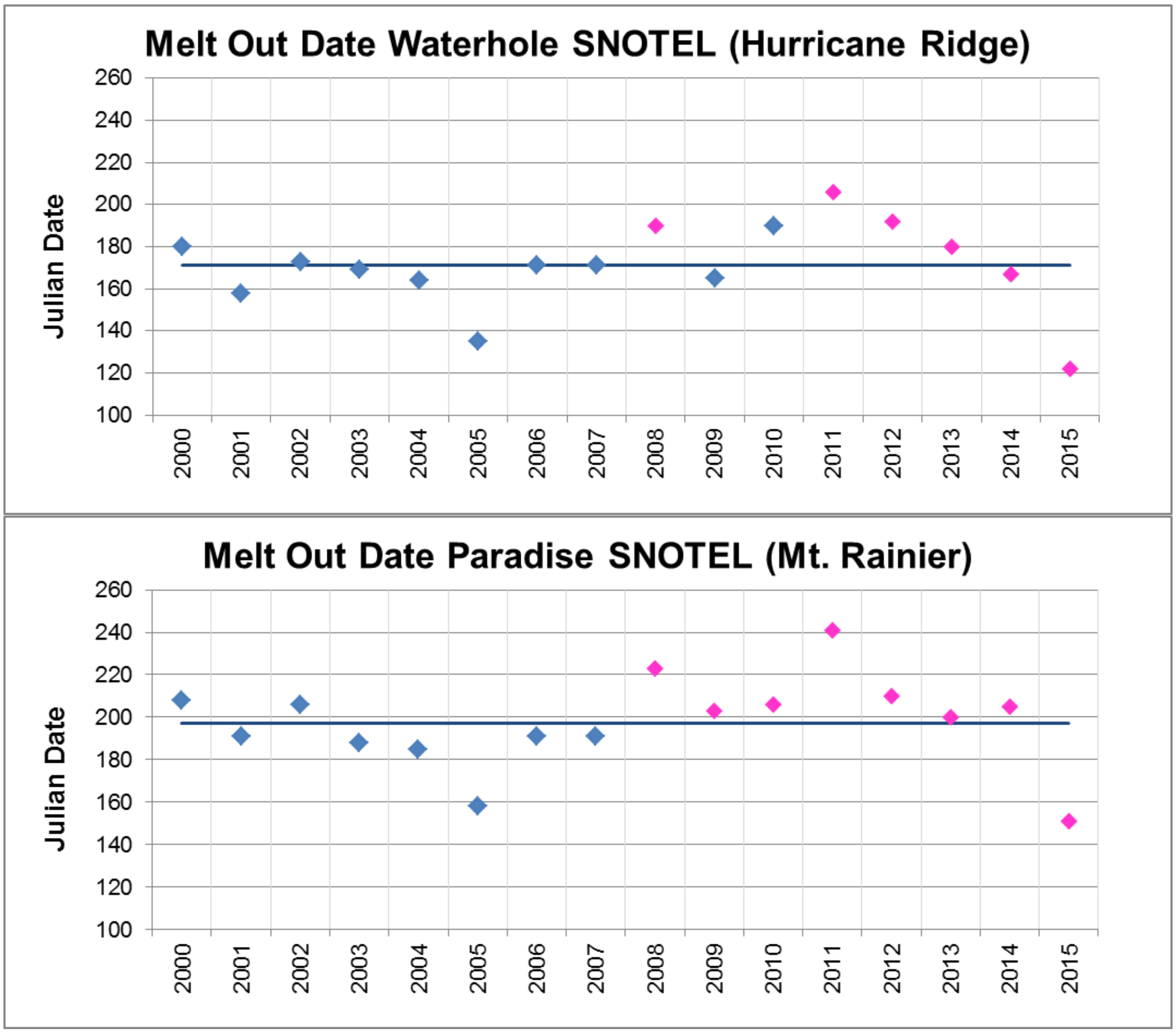

Figure A1. Snow Melt Out Date (last day of snow on ground) at the Waterhole SNOTEL (Hurricane Ridge, OLYM) and Paradise SNOTEL (MORA) for the period 2000 to 2015. Horizontal lines indicate the average melt out date for the time period. Magenta data points indicate years when an elk census occurred.

The early melt moved forward the date of leaf emergence in these meadows while warm dry conditions appeared to accelerate the rate of growth and then ultimately, the timing of senescence. One method for quantifying this effect is by comparing accumulated growing degree-days (AGDD). Growing Degree Days (GDD) are derived from air temperature and provide a measure of heat commonly used to predict plant development rates.

GDD is calculated in this report using the following formula:

$$GDD = T_{AVG} - T_{BASE}$$

$$\text{If } T_{AVG} < T_{BASE} \text{ then } GDD = 0$$

where T_{AVG} is the daily average air temperature and T_{BASE} is the temperature below which the process of interest (e.g. plant growth) does not progress. When using GDD to understand rates of plant growth, the value of T_{BASE} varies depending on the species and growth stage (Wang, 1960). Literature sources document a range of base temperatures used to calculate GDD (Gordon 1993, Miller 2001). These typically range from 32°F for the hardiest of graminoids (Frank 1989, McMaster 1988), to warmer base temperatures of 40 and 50°F for less hardy grasses, forbs and woody perennials (Briggs 2000, OSU 2013).

Figures A2 and A3 show the accumulated growing degree-day (AGDD) values for Hurricane Ridge (OLYM) and Paradise (MORA) during elk survey years using a 40°F base value. AGDD was calculated by adding daily GDD values beginning from the date of snow melt at a high elevation reference station. The assumption is that higher AGDD values early in the season reflect accelerated plant growth and early availability of food. Higher values late in the season may indicate accelerated senescence of these same plant food sources. The figures help to highlight the unusual conditions and accelerated plant phenology observed in 2015 at both parks. AGDD values at OLYM are typically in the 600 to 800 range (median value of 704) during our elk census. In 2015, despite bumping forward the date of flights to mid-August, the AGDD value at OLYM had reached 1245. The separation of 2015 AGDD values at MORA is even more obvious. 2015 AGDD value is 1148, compared with a median value of 422 in all other survey years.

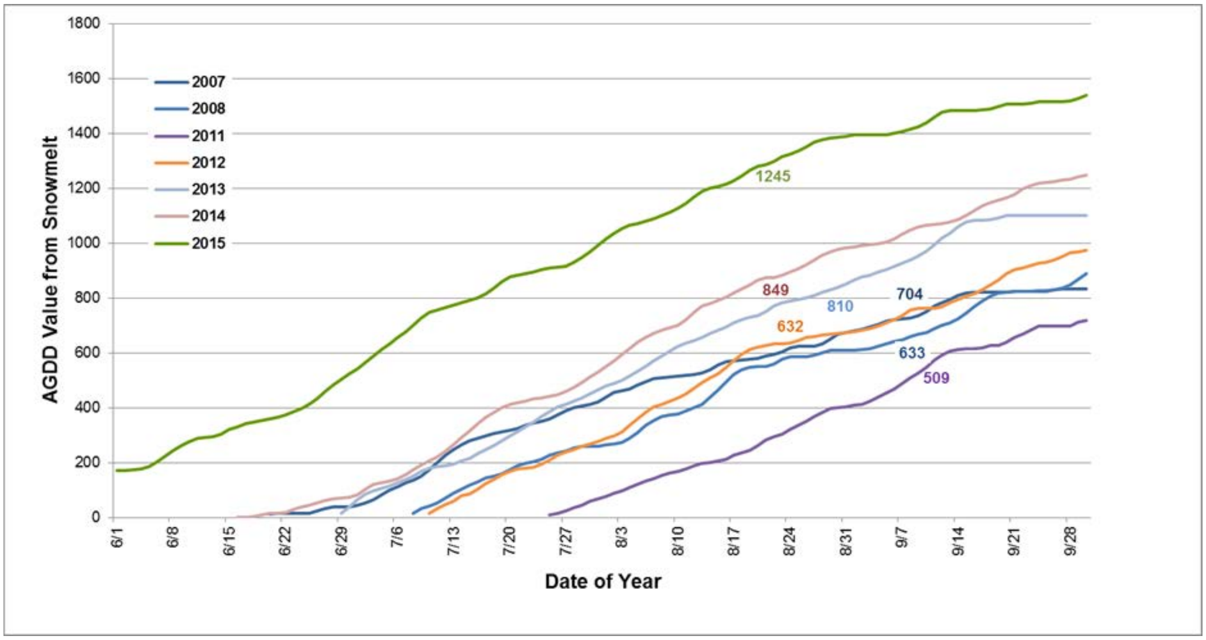

Figure A2. Accumulated Growing Degree Days (AGDD) values for Hurricane Ridge (OLYM) during elk census years. Displayed values indicate the AGDD on the first day of elk flights that year.

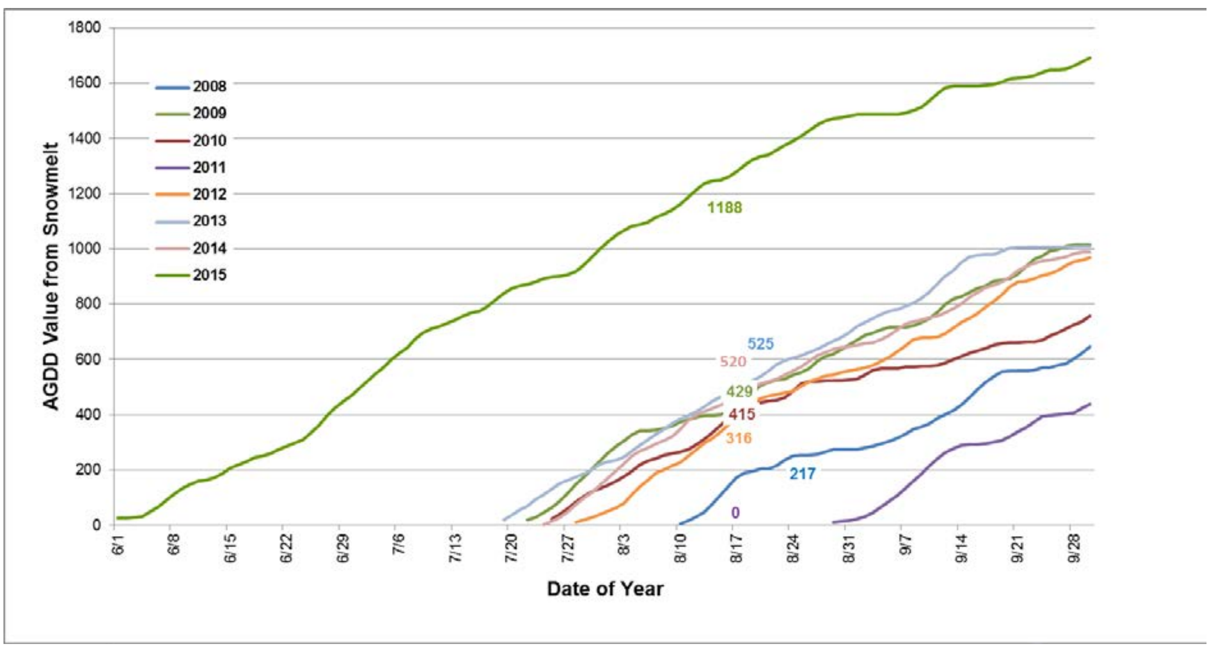

Figure A3. Accumulated Growing Degree Days (AGDD) values for Paradise (MORA) during elk census years. Displayed values indicate the AGDD on the first day of elk flights that year.

Appendix B: Other wildlife recorded during elk surveys in Mount Rainier National Park, 2015.

Survey Area (flight)	Species	Number of groups recorded	Number of individuals recorded
South 1	Black Bear (*Ursus americanus*)	4	6
	Deer (*Odocoileus hemionus*)	4	14
	Marmot (*Marmota caligata*)	1	1
	Mountain Goat *(Oreamnos americanus)*	3	8
South 2[1]	Bald Eagle (*Haliaeetus leucocephalus*)	1	1
	Black Bear	1	1
	Deer	1	1
	Mountain Goat	5	7
North[1]	Black Bear	1	1
	Deer	1	1
	Falcon spp (*Falco spp*)	1	1
	Mountain Goat	12	76
	Golden Eagle (*Aquila chrysaetos*)	1	1

[1] other wildlife were only recorded one flight of South 2 and one flight in the North.

Appendix C: Other wildlife recorded on elk surveys in Olympic National Park, 2015.

Survey Area	Species	Number of groups recorded	Number of individuals recorded
Core	Black Bear (*Ursus americanus*)	4	4
	Coyote (*Canis latrans*)	1	1
	Mountain Goat *(Oreamnos americanus)*	15	23

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