National Park Service
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Natural Resource Stewardship and Science

Elk Monitoring in Lewis and Clark National Historical Park

2008-2012 Synthesis Report

Natural Resource Technical Report NPS/NCCN/NRTR—2014/837

ON THE COVER
Bull elk photographed by a motion-sensitive camera near the South Slough Trail
Photograph by: Lewis and Clark National Historical Park

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Executive Summary

Maintaining elk (*Cervus elaphus roosevelti*) herds that frequent Lewis and Clark National Historical Park (NHP) is central to the park's purpose of preserving the historic, cultural, scenic, and natural resources associated with the winter encampment of the Lewis and Clark expedition. Elk were critically important to the Lewis and Clark expedition in providing food and hides that sustained the expedition during the winter of 1805-06 and supplied them for their return east during 1806. Today, elk remain a key component of interpreting the Lewis and Clark story to over 200,000 park visitors each year at the Fort Clatsop visitor center.

In 2008, the US Geological Survey (USGS) began collaborating with Lewis and Clark NHP and the NPS North Coast and Cascades Network to develop a protocol for monitoring long-term changes in the magnitude and spatial patterns of elk use within and adjacent to Lewis and Clark NHP (Griffin et al. 2011). Specific objectives of the monitoring program were to measure trends in (1) relative use of the Fort Clatsop unit by elk during winter; (2) the proportion of areas where elk sign is present in the Fort Clatsop unit in winter; and (3) the frequency of elk sightings from roads in and around the Fort Clatsop unit. This report synthesizes the results of the first four years of monitoring elk distribution and use in Lewis and Clark NHP from 2008-2012. We also present data from FY2012 (Appendix 1), in lieu of an annual report for that year.

We used fecal pellet group surveys as the cornerstone for monitoring trends in both relative use of the Fort Clatsop Unit by elk and the proportion of areas where elk sign was present at the end of winter. We estimated pellet group density based on data collected from a network of fecal pellet plots distributed systematically throughout the unit. We developed a double observer sampling scheme that enabled us to estimate detection biases and improve the accuracy of pellet group density estimates. We computed the estimated detection probability for any pellet group observed; this probability was a function of the pellet group size and stage of decay, as well as lighting and vegetation conditions, and the number of observers (one or two) searching for pellets in that subplot. We then used these estimated detection probabilities to adjust the raw counts of the detected pellet groups to account for groups that likely went undetected under similar pellet and environmental conditions (each observed pellet group was weighted by the inverse of its estimated detection probability). We also used results from the late winter fecal pellet surveys to quantify the proportion of areas where elk pellets occurred (PAO), which was based on the presence of fecal pellet groups and estimation of detection biases (i.e., accounting for pellet groups that likely went undetected by both observers). In this synthesis, we report temporal trends in both pellet group density and PAO from 2008-2012, based on weighted linear regression analyses as well as spatial variation of pellet group densities over time.

We completed late winter fecal pellet surveys at 61-66 plots annually, depending on yearly variation in access. We cleared fecal pellets at survey points in late October / early November each year and returned in late February / early March to count pellet groups left by elk over the winter. The estimated probability that a pellet group was detected by any one observer during late winter was affected most by the pellet group size and was less affected by decay class and lighting conditions. Per-observer detection probabilities ranged from as low as ~10-15% for single pellets to ~85-90% for pellet groups with 50 pellets. Average pellet group density in the Fort Clatsop unit ranged annually from 0.58 (+/- 1.43 standard error [SE]) to 0.93 (+/- 2.25 SE) pellet groups per 3-m radius subplot. Pellet group density declined over time, at approximately

8.8% per year (+/- 2.5% SE), but that slope was not statistically distinguishable from zero (2-tailed P=0.16). Following correction for detection biases, the proportion of surveyed points used by elk (i.e., PAO) ranged from 0.44 (+/- 0.07 SE) to 0.53 (+/- 0.07 SE) during the 4 winters. The estimated proportion of areas where elk pellets occurred (PAO) declined at a rate of 2.6% per year (+/- 1.2% per year SE), but that trend also was not statistically distinguishable from zero (2-tailed P=0.17). Statistical significance of a measure's trend depends on both the magnitude (i.e., slope) of the observed trend and the number of years the trend continues in the same increasing or decreasing direction. Through simulation modeling we determined how many additional years of surveys would be required to reveal a statistically significant trend, based on the same trends in pellet group density and PAO, and associated variation, observed from 2009-2012. Assuming the same trends persist in the future, simulations indicated that there is a 70% probability that a statistically significant trend would be detected after two more years of conducting pellet group surveys.

Relative use by elk during winter, as indexed by elk pellet group density, was generally greatest in the southeast region of the Fort Clatsop unit in or near the large freshwater marsh at the mouth of Colewort Creek and adjacent upland areas. Pellet group density was also higher than average in the north-central forested area, not far from a privately-owned pasture north of the park boundary. This spatial pattern in pellet group densities across the Fort Clatsop unit was consistent across all four years, although specific pellet group densities varied from year to year. Pellet group density declined significantly over time at two points in the southeast of the Fort Clatsop unit, even though pellet group density at those points remained higher than the unit average. Pellet group density increased significantly over time at one point in the north-central region, and at one point in the south-central region of the unit, indicating a slight shift in the distribution of elk use within the Fort Clatsop Unit over the four years.

As an index of visitors' opportunities to see elk in and around the Fort Clatsop Unit, we conducted replicated roadside elk surveys 3-5 times monthly during February, April, June, August, October and December 2008-2012. During each morning of survey, we searched for elk along four routes that totaled 32 km. We examined bimonthly trends in the numbers of elk groups seen, the total number of elk seen, and the observed composition ratios for those six months of the year. The average number of elk groups seen per survey ranged from 0.75 (+/- 0.32 SE) during February to a peak of 1.95 (+/- 0.36 SE) during June. Despite this seasonal variation in numbers of elk groups seen, the average total number of elk seen per morning was less variable. The average ratios of antlered elk to antlerless adult elk (i.e., bulls:cows) and calves to antlerless adult elk (i.e. calves:cows) varied seasonally, with the highest of both average ratios observed in August. We detected no significant trends in the average number of elk groups and total numbers of elk seen per survey from 2008-2012. Similarly, ratios of calves and antlered elk per antlerless elk did not differ over time.

Elk groups were frequently seen from January to August in the southeast region of the Fort Clatsop unit, in the vicinity of Colewort Creek. Outside of NPS lands, we observed elk most frequently in open areas near the Astoria regional airport, in the pastures and forests immediately north of the Fort Clatsop unit and, prior to the construction of a residential development, in a pasture northwest of the Fort Clatsop unit.

Elk monitoring at Lewis and Clark NHP is still in its initial years and additional monitoring will be required to verify trends that appear to be emerging. For example, the initial monitoring suggested incipient declining trends in both pellet group density and proportion of plots with pellets present, as well as, potentially, a small shift in elk distribution away from a new trail that was recently constructed in the southeast portion of the Fort Clatsop unit. Continued monitoring will aid in determining whether this local change in distribution persists (or, alternatively, resulted from short-term random variation), and whether there will be any positive or negative effect in the northern portion of the unit where a new trail has been constructed. High variability in road counts prevented our ability to find any clear trend in numbers or composition of elk observed in and near Fort Clatsop, but changes in the patterns of observations of elk from roadways suggest that residential development outside the park has reduced the available habitat for elk in some of the areas surveyed, and may have affected spatial use patterns of elk adjacent to some areas of the park. In addition to monitoring future effects of land use changes outside the park, continued monitoring may also prove useful for assessing elk responses to natural succession in forests disturbed by windthrow in December 2007 and to NPS vegetation management activities such as variable density thinning in the forest, trail development, and restoration at Otter Point tidal area and Colewort Creek Slough.

Acknowledgments

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Introduction

The preservation of Roosevelt elk (*Cervus elaphus roosevelti*) herds that frequent Lewis and Clark National Historical Park (NHP) is central to the park's purpose of preserving the historic, cultural, and natural resources associated with the arrival of the Lewis and Clark Expedition in the lower Columbia River area (U.S. Congress 2004). Elk were an important source of food and materials for the Chinookan and other indigenous Native American tribes that inhabited the region for millennia prior to the arrival of the Lewis and Clark expedition. Elk were also centrally important to the Corps of Discovery during their entire expedition, as elk meat was an important staple throughout the voyage. Specifically, the abundance of elk around the Netul River (now called the Lewis and Clark River) contributed to the expedition's choice for the winter encampment site that would become Fort Clatsop (DeVoto 1997). Members of the Corps of Discovery shot hundreds of elk (Burroughs 1961), including more than 130 elk over the course of the 1805-1806 winter in the Lewis and Clark NHP region, and used elk skins to make over 350 pairs of moccasins in preparation for the return journey.

Today, elk viewing opportunities in the park and surrounding region (Figure 1) generate broad appeal with the visiting public. Elk sightings are a valued aspect of the park visitor's experience, to the extent that suggested locations to see elk near Lewis and Clark NHP are listed in NPS park visitor guidebooks. Some interpretive programs at Lewis and Clark NHP feature elk and include lessons in identifying elk and elk sign (pellets, hoofprints) found on walks in the park.

In 2008, the U.S. Geological Survey (USGS) and the National Park Service North Coast Cascades Network (NCCN) Inventory and Monitoring Program began working together to monitor long-term trends in elk use of Lewis and Clark NHP and the surrounding environment as a key component of understanding the effects of regional development and park management activities on elk use of the park. The most important agents of change with the potential to influence elk population trends in and near Lewis and Clark NHP are an increasing human population and associated land development pressures. Elk herds in the region move across public and private lands that may be subject to urban development, forest management, hunting, and agricultural practices. NPS lands, where hunting is always prohibited, can potentially serve as habitat for elk so long as they are connected to other habitats where elk can meet their needs for food, water, and cover.

The goal of elk monitoring is to detect changes in the magnitude and spatial patterns of elk use in landscapes within and adjacent to selected areas of Lewis and Clark NHP. Specific objectives of elk monitoring in Lewis and Clark NHP are to monitor trends in (1) elk relative use and spatial distribution within the Fort Clatsop unit during winter; (2) the proportion of areas where elk sign is present in the Fort Clatsop unit in winter; and (3) the frequency of elk sightings from roads in and around the Fort Clatsop unit. We focused studies of elk relative use and spatial distribution in the Fort Clatsop unit during winter primarily because of operational and funding constraints. Initially, we considered monitoring relative use and spatial distribution of elk based on sign surveys conducted seasonally, but funding was not sufficient and there were other operational and logistical constraints (Griffin et al. 2011). We conducted roadside surveys of elk in and around the Fort Clatsop unit throughout the year because they are inexpensive and provide temporal indices of elk distribution in and around the Fort Clatsop unit. Griffin et al. (2011)

described in detail the rationale for selecting the three primary indicators of elk use and distribution.

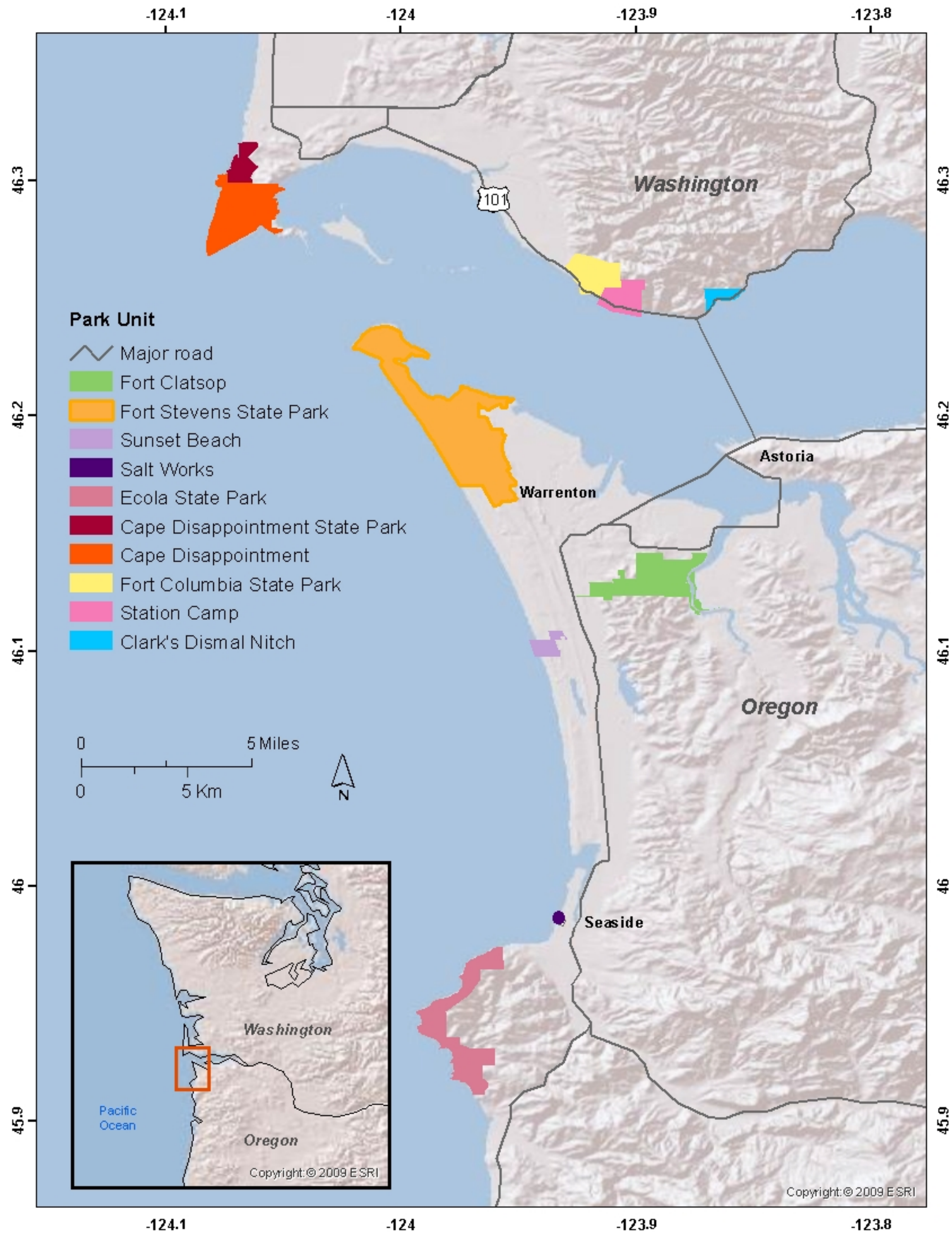

Figure 1. Lewis and Clark National Historical Park (NHP) units and State Park units. The box on the inset map shows the location of Lewis and Clark National Historical Park in the regional context of Oregon and Washington. The 495-hectare (1221 acre) Fort Clatsop unit is shown in green.

This monitoring program was designed to reveal patterns of elk distribution within and near the Fort Clatsop unit of Lewis and Clark NHP. This unit was selected because of the historical importance of elk near the fort, and because the Fort Clatsop unit is the focus of several NPS management activities with the potential to benefit or affect elk populations. For example, Lewis and Clark NHP has an active ecological restoration program that aims to recreate ecological conditions that Lewis and Clark encountered (NPS 2011). In 2004, the park acquired about 400 hectares (ha; ~1000 acres) of second- and third-growth industrial forests that bore little resemblance to the historical forest structure. Subsequently, the park developed a management plan to thin these forests to accelerate the development of late-seral forest conditions (NPS 2011). Additionally, severe weather on December 2-3, 2007 blew over thousands of trees on ~87 ha (~214 acres) of the unit, creating dozens of forest canopy gaps that range from ~0.03 to ~24 ha (~0.07 to ~60 acres). The NPS was the only large land holder in the region that did not conduct commercial salvage operations after the storm (Carla Cole, Lewis and Clark NHP, pers. comm.). The park has also been active in restoring the tidally influenced wetlands at Otter Point and Colewort Creek slough that were previously diked and disconnected from tidal processes. Lastly, starting with construction of the 'Fort to Sea' trail in 2005, and culminating with the completion of the 'Loop B' trail in 2013, the park will have created over 9 new miles (~14 km) of hiking trails on former timber roads and previously undeveloped land. Fine-scale elk monitoring across the Fort Clatsop unit may indicate how elk distribution and use patterns respond to restoration programs, trail construction, and other proposed management activities, and will allow managers to adapt programs accordingly.

We monitored changes in relative use of the Fort Clatsop unit by elk during winter based on fecal pellet surveys used to estimate both pellet group density and the proportion of areas where elk pellets occurred. Elk fecal pellet group density is a reliable index to the relative intensity of use so long as decay rates and detection probabilities are comparable across the sampled area, or can be estimated (Weckerly and Ricca 2000, Jenkins and Manly 2008). We reduced the influence of variable decay rates on pellet group counts by clearing all fecal pellets from survey plots during the late fall, before returning in the late winter to count pellet groups that had accumulated. We accounted for the fact that different elk pellet groups have different detection probabilities by using double-observer methods to estimate the detection probability for each pellet group. We then applied corresponding correction factors to estimate the number of pellet groups that went unseen. Each sampled point had its own measure of elk fecal pellet group density, which we used to assess the annual spatial distribution of elk use across the entire Fort Clatsop unit landscape, as well as changes in distribution over time.

We estimated the proportion of areas where elk sign was present following winter using single season occupancy modeling methods (MacKenzie et al. 2006). Occupancy models rely on conducting independent surveys of a subset of plots to estimate the influence of detection biases on the estimation of presence. Therefore, two observers searched independently for elk sign (elk fecal pellets) within fecal pellet survey plots, enabling us to obtain a less biased estimate of proportional occurrence of fecal pellet groups throughout the Fort Clatsop Unit. We refer to the proportion of surveyed points where fecal pellets were present in late winter as the proportion of areas where elk pellets occurred (PAO).

To measure the elk viewing opportunities that are available to visitors, we conducted standardized morning road surveys on a defined set of roads in and near the Fort Clatsop unit. In alternate months, we repeated the surveys so that we would have several measures of the number of elk groups seen, the total number of elk seen, and the composition of elk groups in terms of the relative numbers of antlered (i.e., bull), antlerless adult, and calf elk seen.

In this report we synthesize results from the first four years of monitoring trends in elk use and distribution around the Fort Clatsop unit of Lewis and Clark NHP. We present estimates of annual pellet densities, and trend estimates for average elk pellet group densities and PAO. We also assess changes over time in the spatial distribution of elk pellet group density. Using the road survey data, we evaluate monthly trends in the number of elk groups seen per morning, the total number of elk seen per morning, and the composition of observed elk groups.

Methods

Pellet Group Surveys

Sampling Design

We sampled pellet groups within plots that were centered on points distributed systematically in a hexagonal pattern throughout the Fort Clatsop unit of Lewis and Clark NHP (Figure 2). Points were distributed such that each was 250 m from each of up to six adjacent points (Figure 2). There were 82 points in the sample frame, but we excluded some sampling points if they were seasonally inundated by water (6 points), they were inside the legislated area of the park but outside the park boundaries (3 points), or because of safety issues (steep slopes, extreme blowdown, or blackberry brambles; 8 points). As a result, 65 points comprised the sample, although there was some annual variation in the number of points surveyed due to logistics and safety issues. Additional points may be added in the future as appropriate, given changes in vegetation conditions, water inundation patterns, or park boundaries.

At each survey point, we established a 9-m radius plot used to describe ambient light levels, understory and overstory vegetation attributes. Within each plot we established four 3-m radius subplots 6 m from the survey point in each of the cardinal directions where we searched for elk pellet groups (Figure 3). The subplots served as the basis for determining presence and density of elk pellet groups associated with each point.

The annual cycle of fecal pellet sampling consisted of two sessions: fall and late winter. During the fall session (in the last week of October to first week of November) we cleared all subplots of previously existing fecal pellet groups. We then returned to the plots in the late winter session (last week of February to first week of March) to quantify pellet group abundance. Sampling sessions were separated by approximately 110 days to allow sufficient time for measurable deposition of fecal pellets while also minimizing decomposition and disappearance of pellet groups within the period (Jenkins and Manly 2008).

Field Methods

In 2008 and 2009, when survey points were first established throughout the Fort Clatsop unit, survey team members used a GPS unit to navigate to within 1 m of each target coordinate, and assessed each plot for safety and potential flooding. They also recorded additional GPS data, which was processed later to improve accuracy of UTM coordinates recorded in the field. Each survey point was permanently marked with a rebar stake. Team members also located and marked subplot centers with numbered, lettered flags as depicted in Figure 3.

For crew safety and logistical reasons, we used two-person teams to conduct the pellet surveys. In addition, while traveling to pellet survey points, observers recorded whether or not they observed any elk pellet groups. A complete presentation of pellet survey methods is available in Griffin et al. (2011), SOP 6: Conducting Pellet Counts. We present a brief summary here.

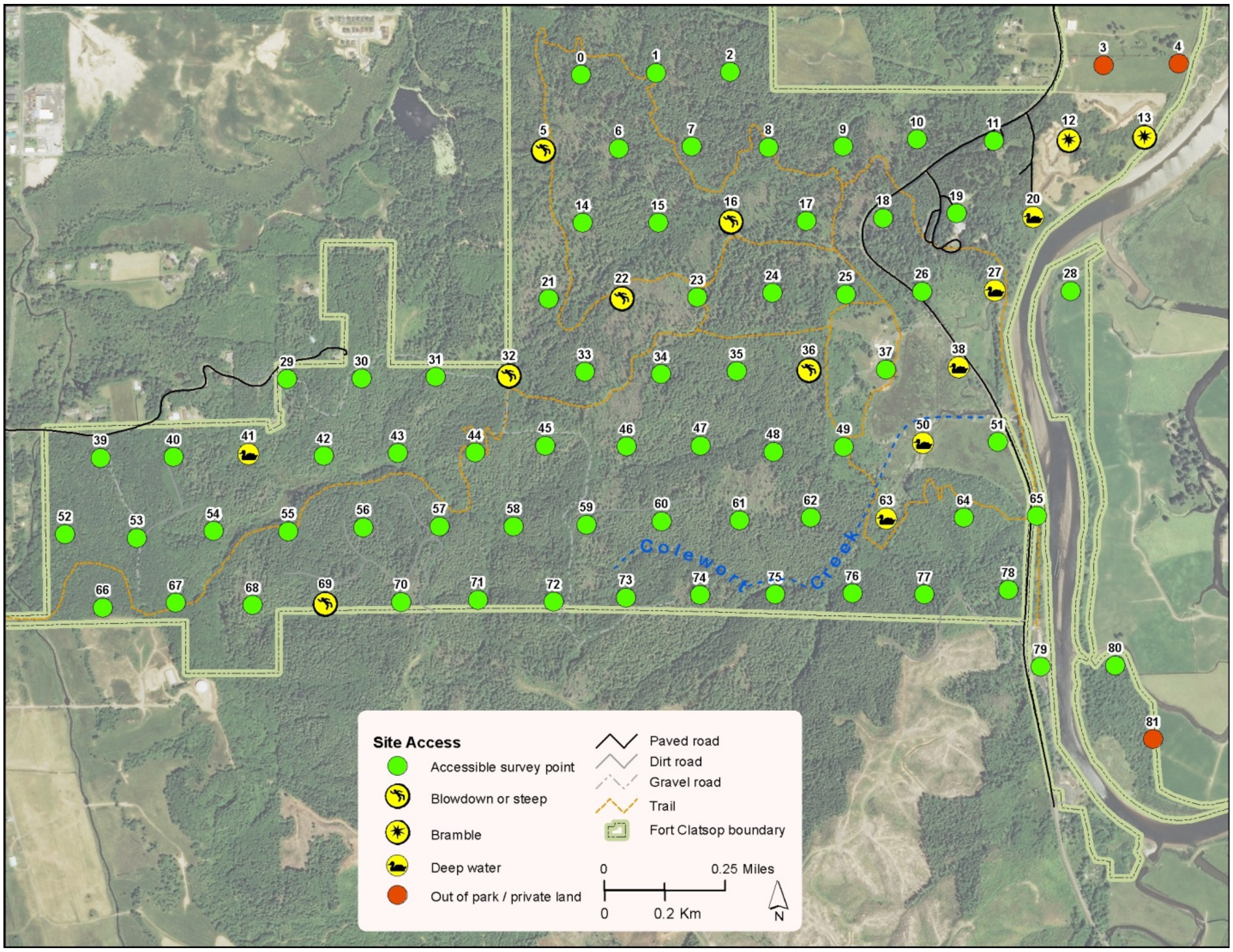

Figure 2. Points for the elk pellet survey within the Fort Clatsop unit. Points labeled with a green dot were accessible. Points with yellow symbols were inaccessible, unsafe, or under water. The satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture). Mottled grey-green areas within the forested part of the Fort Clatsop unit were areas of windthrown trees (also called 'blowdown') caused by a windstorm in December 2007.

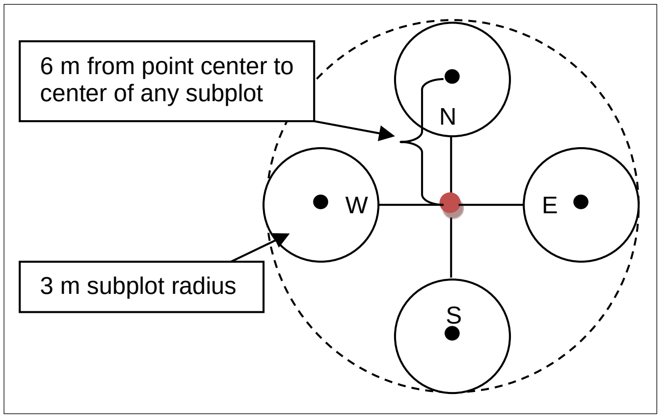

Figure 3. Schematic diagram of a survey point. A 9-m radius plot encompasses four 3-m radius subplots. Subplot centers are 6 m north, south, east and west from the point's center.

During fall of each year, field crews visited each of the survey points to remove all pellet groups from each of the four subplots. Clearing was necessary to standardize the time over which pellet groups accumulated until they were counted at the end of winter. In 2010, we modified the methods used to clear pellet groups during the fall, to better reflect budgetary constraints. During 2008 and 2009, we enumerated pellet groups using double-observer data recording methods described below before the plots were cleared. During 2010 and 2011, the observers simply counted and removed all pellet groups from the plots without recording any other data. In 2010 and 2011, all four subplots were searched by both observers and the total number of pellets removed was recorded; recording the numbers of pellet groups removed by each observer served as documentation that all four subplots were inspected.

In late winter surveys, the 2-person teams first recorded general attributes within the 9-m radius plot that might influence elk use and elk pellet group detection probability such as vegetation characteristics, lighting conditions, and the percentage of windthrown trees. The purpose of recording these general data at the plot level is two-fold – the attributes may be factors used in the analysis of pellet group detection probabilities (e.g., lighting conditions) or occupancy patterns (e.g., blowdown); and they may signal changes in vegetation structure or composition that affect future observations at survey points.

After recording the habitat attributes, each team member independently searched for elk pellet groups in two of the four subplots. This resulted in each team member serving as a primary observer for two of the four subplots and all four subplots being searched by a primary observer. In each subplot, primary observers recorded the percent of vegetation cover below 1 m height that could obscure views of pellets. Observers used a collapsible 3-m long stick to determine whether individual pellet groups were within or outside of the subplot. Each observer noted the approximate location of detected pellet groups on a circular sketch of the subplot. Pellet groups in a single subplot were distinguishable from one another based on location, dispersion, and differences in their state of decay. Observers recorded the number of pellets and pellet clumps per group. A pellet clump was an aggregate of fecal material, roughly equivalent in volume to ten elk fecal pellets. Observers also noted the decay class for each pellet group. The four decay classes categorized elk pellet groups according to subjective measures of texture, apparent decomposition, and evidence of fungal and plant growth on pellet surfaces. Along with light level and vegetative cover in the subplot, the size and decay class of the pellet groups are used in modeling pellet detection probabilities.

After the primary subplot surveys were completed, each observer resurveyed one randomly selected subplot that was previously surveyed by his or her crew partner. In this manner, two of the four subplots were searched by both team members (whereas the other two subplots were searched only once). After the secondary surveys were completed, the observers compared notes and sketches and recorded which pellet groups had been seen by one or both team members. Through a combination of discussion, comparison to sketches, and working together in the resurveyed plots, the crews reliably distinguished which groups were seen by both or only one observer. Observers then cleared all pellets from all of the subplots.

Data Management

Following each elk pellet survey or road survey data collection event, data were entered into the project database. Database records were later verified for complete and accurate transcription by retrieving and visually comparing the data associated with each sampling event against the original forms. Once all data for the season were entered and verified, a rigorous quality review was conducted on the data set by running a set of pre-built validation queries to check for completeness, missing or out-of-range values, logical consistency, and structural integrity. Errors identified during this review were corrected where possible, and annotations related to specific issues raised by each query were stored within the project database as needed and appropriate.

Data Analysis

Pellet Group Density

We defined late winter pellet group density, G, as the number of pellet groups per subplot. The symbol $\hat{G}_{i,t}$ denoted the average estimated pellet group density per subplot at a single point *i* and year *t*. Throughout this report, the 'hat' symbol, $\widehat{\ }$, signifies an estimate. Averaged throughout the Fort Clatsop unit, the estimated arithmetic mean pellet group density for year *t* was denoted as $\hat{G}_{mean,t}$.

Detection Model Development

We denoted the expected probability that a single observer detected any given pellet group, j, as $\hat{p}_{group,j}$. Modeling detection probabilities for a single observer was necessary for later obtaining unbiased estimates of $\hat{G}_{i,t}$ at each of the survey points. The estimates of pellet group detection probabilities, $\hat{p}_{group,j}$, were used to determine correction factors, $\hat{w}_j$ used to adjust sightings of individual pellet groups to account for imperfect detection probabilities (see below, *Adjusting Pellet Group Counts to Account for Detection Bias*).

We used pellet groups that were observed by at least one observer in double-counted subplots to estimate a detection model that estimated $\hat{p}_{group,j}$ as a function of recorded covariates. The recount code for each pellet group observed in recounted subplots indicated whether an individual pellet group was seen only by the first observer, only by the second observer, or by both observers. In preparation for model fitting, we designed a summary query in the database, **qs_Pellet_obs_covars_model_build_MARK_input**, which outputs a table of covariate data for each pellet group that was observed in a recounted subplot. The first covariate, "group_size," was an integer equal to the number of pellets in the group, plus ten times the number of clumps in the group (defined previously as a fused mass equal to that of approximately 10 fecal pellets). Before conducting the analysis, we transformed this to the natural log of pellet group size; many studies of detection use this transformation prior to analyses (Rice et al. 2008, McCorquodale et al. 2012). The second covariate, "cover," was an integer value from 0 –100 describing the percentage of cover below 1-m in height that could obscure the view of a pellet group; this was a single value recorded for the subplot. The third covariate, "light," was a dummy variable (binary: 0 or 1) that indicated light levels measured at the plot level. We tested for an effect of 'dim' light; pellet groups found under 'medium' and 'bright' light levels had a value for light of 1, but pellet groups found under 'dim' light levels had a value for light of 0 (Griffin et al. 2011). The final covariate, "decayed," was a dummy variable where the most decayed pellet groups (decay class 4) were contrasted with all other decay classes (1, 2, and 3); class 4 pellet groups had a value of 1 for the "decayed" covariate, while all other pellet groups had a value of 0 (Griffin et al. 2011).

We pooled four years of data for analysis of pellet group detection probability. Estimates of detection probability included pellet group detection data from subplots surveyed in all late winter sessions, and from fall 2008, 2009, and 2010 because these were years when fall session methods were identical to the spring methods.

We included 15 models in the candidate set that we fit to pellet group data from recounted subplots (Table 1). We used program MARK (White and Burnham 1999) to structure each model as a logistic regression describing the per-observer probability that pellet group *j* is detected, given the covariate values recorded. We modeled each covariate as an additive effect. We chose the most parsimonious models for detection probability, using models with AIC_c scores within 4.0 of the highest ranked model in model averaging (Burnham and Anderson 2002). We entered the MARK-estimated β coefficient parameters and AIC_c weights from each of the top models into the database table **tbs_Model_Parameters**.

Table 1. Model structure of 15 candidate Huggins models used to identify which of the candidate models best fits the data for pellet groups seen by one or two observers. In each model name, the p refers to $\hat{p}_{group,j}$, that is the per-observer probability of detection by either observer, given the covariates specific to pellet group j. The number of parameters, *k*, is also shown for each model.

Model Number and Name	***k***
1. p(.)	1
2. p(ln(Group_size))	2
3. p(Cover)	2
4. p(Light)	2
5. p(Decayed)	2
6. p(ln(Group_size) + Cover)	3
7. p(ln(Group_size) + Light)	3
8. p(ln(Group_size) + Decayed)	3
9. p(Cover+Light)	3
10. p(Cover+Decayed)	3
11. p(Light+Decayed)	3
12. p(ln(Group_size) + Cover + Light)	4
13. p(ln(Group_size) +Light + Decayed)	4
14. p(Cover + Light + Decayed)	4
15. p(ln(Group_size) + Cover + Light + Decayed)	5

Adjusting Pellet Group Counts to Account for Detection Bias

To adjust for the unknown number of pellet groups that were not detected by any observer, we weighted each observed pellet group using a correction factor that varied as a function of detection probabilities specific to each pellet group. We used these correction factors to reduce the bias in density estimation that results from the failure to detect all the pellet groups present. For subplots that were counted by a single observer (i.e., generally two of the four subplots at a surveyed point), each observed pellet group was corrected by the factor $\hat{w}_{j1}$.

$$\hat{w}_{j1} = \frac{1}{\hat{p}_{group,j}}$$

For example, a pellet group observed under conditions in which $\hat{p}_{group,j}$ = 0.5 would be corrected by a factor of 2.0 to account for pellet groups of comparable size and environmental conditions that were presumably missed. This type of correction factor has been applied widely to account for missed observations of large mammals in aerial surveys (Samuel et al. 1987) and to correct pellet group observations to reduce detection biases (Jenkins and Manly 2008).

Correction factors were slightly more involved for pellet groups found in subplots that were searched by two observers because the correction factor had to account for the probability of being observed by at least one of the two observers. The expected probability that a pellet group was *not* detected by one observer was (1 - $\hat{p}_{group,j}$). Because the two observers were independent, it followed that the expected probability that both observers did *not* detect a given pellet group is $(1 - \hat{p}_{group,j})^2$. This means that the expected probability that at least one of the observers *did* detect the pellet groups was $1 - (1 - \hat{p}_{group,j})^2$. For subplots that were surveyed by both observers, each observed pellet group was corrected by the inverse of the probability that it was detected by at least one observer; the formula for that correction factor, $\widehat{w}_{j2}$, is shown below.

$$\widehat{w}_{j2} = \frac{1}{1 - (1 - \hat{p}_{group,j})^2}$$

For example, for a pellet group in which $\hat{p}_{group,j}$ = 0.5, the probability that at least one of the two observers saw the pellet group is 0.75 and the associated correction factor would have been 1/0.75, or 1.33, to account for groups missed under similar conditions. This example shows that, for any two pellet groups with identical covariates, $\widehat{w}_{j2}$ is always closer to one than $\widehat{w}_{j1}$. The only source of that difference is that the pellet group in a recounted subplot has more opportunity to be seen by at least one observer.

Uncertainty in the estimation of the detection probability, $\hat{p}_{group,j}$, affected variance estimates of the correction factor for an individual pellet group. The variance of the inverse of an estimated parameter (i.e., $1/\hat{p}_{group,j}$) may be approximated using the delta method (Casella and Berger 1990, Thompson 2002). We calculated the variance for the one-observer correction factor, $Var(\widehat{w}_{j1})$, using the equation below (Griffin et al. 2011, Appendix E).

$$Var(\widehat{w}_{j1}) = \frac{Var(\hat{p}_{group,j})}{(\hat{p}_{group,j})^4}$$

Using the same example of a pellet group with a per-observer detection probability of $\hat{p}_{group,j}$ = 0.5, and a corresponding value of 2.0 for $\widehat{w}_{j1}$, we can estimate the variance for $\widehat{w}_{j1}$using the estimates for $\hat{p}_{group,j}$ and $Var(\hat{p}_{group,j})$. Supposing that $Var(\hat{p}_{group,j})$ = 0.2, then the variance of that estimate for $\widehat{w}_{j1}$ is $0.2 / (0.5)^4 = 3.2$

For pellet groups in subplots that were searched by two observers, the variance of the resulting correction factors is shown below. As with $Var(\widehat{w}_{j1})$, $Var(\widehat{w}_{j2})$ was affected by uncertainty in the estimate of $\hat{p}_{group,j}$ (Griffin et al. 2011, Appendix E).

$$Var(\widehat{w}_{j2}) = \frac{4\left(1 - \hat{p}_{group,j}\right)^2 Var\left(\hat{p}_{group,j}\right)}{\left[1 - \left(1 - \hat{p}_{group,j}\right)^2\right]^4}$$

Again using the same example of a pellet group with a per-observer detection probability of $\hat{p}_{group,j}$ = 0.5, if we suppose that $Var(\hat{p}_{group,j})$ = 0.2, then the variance of that estimate for $\widehat{w}_{j2}$ would be 4*(1-0.5)^2*(0.2) / [1-(1-0.5)^2]^4 = 0.2 / 0.3164 = 0.632. As this example shows, for any two pellet groups with identical covariates, $Var(\widehat{w}_{j2})$ is smaller than $Var(\widehat{w}_{j1})$. The reason for this is that there is a higher overall probability of such a pellet group being detected in a recounted subplot than in a subplot that is only counted once.

For each year, we used the estimated values of $\hat{p}_{group,j}$ and $Var(\hat{p}_{group,j})$ for all pellet groups found in the late winter survey to determine the correction factor ($\widehat{w}_{j1}$ or $\widehat{w}_{j2}$) and associated variance estimates for each observed pellet group. We computed the expected estimate of $\widehat{G}_{i,t}$ for survey point *i* in year *t* as the sum of the estimated values of $\widehat{w}_{j1}$ or $\widehat{w}_{j2}$ for all pellet groups that were detected in surveyed subplots, divided by the number of subplots surveyed at that point.

In the project database, we structured summary queries (Figure 4) that drew on these model parameters to estimate the average pellet group density for subplots surveyed at each sample point, $\widehat{G}_{i,t}$. We made the database query (**qsub_Pellet_obs_final_with_covars**) to provide the covariate information for each observed pellet group found in late winter surveys in the four-year reporting period. We called on that covariate information for each observed pellet group, along with model parameters from **tbs_Model_Parameters** in another query (**qsub_Pellet_obs_weighted_by_model**) that computed the per-observer detection probabilities for each individual pellet group ($\hat{p}_{group,j}$) based on the most parsimonious model or model-averaged set of models, the variance estimate for that detection probability ($Var(\hat{p}_{group,j})$), the resulting group-specific correction factor ($\widehat{w}_{j1}$ or $\widehat{w}_{j2}$) to apply to that group, and the associated variance in the correction factor for that group ($Var(\widehat{w}_{j1})$ or $Var(\widehat{w}_{j2})$). After computing the group-specific correction factor, $\widehat{w}_{j1}$ or $\widehat{w}_{j2}$, for each of the observed pellet groups, along with the associated variance estimates, $Var(\widehat{w}_{j1})$ or $Var(\widehat{w}_{j2})$, we estimated the number of pellet groups present at each survey point *i* each year *t* (i.e., $\widehat{G}_{i,t}$) adjusted for detection biases. We found the estimated sampling variance for $\widehat{G}_{i,t}$, $Var(\widehat{G}_{i,t})$, as the sum of the sampling variance for the correction factor from pellet groups at that point, divided by the number of subplots surveyed at that point. Each pellet group was an independent observation, so the contributions of each pellet group to total variance were additive. We made the database query **qsub_Gi** to summarize the estimated $\widehat{G}_{i,t}$ values for each point and year for points where pellet groups were found. We made the summary query **qs_Ri_and_Gi** to create the final table of estimated $\widehat{G}_{i,t}$ values for all surveyed points, including zeros for points where no pellet groups were detected.

We denoted average pellet group density per subplot for the Fort Clatsop Unit in year *t* as $\widehat{G}_{mean,t}$. This was the arithmetic mean value of $\widehat{G}_{i,t}$ across all *n* surveyed points. Total variance for average pellet group density in year *t*, $Var(\widehat{G}_{mean,t})$, was the sum of two components of variance: the variance of the mean due to sampling n values of $\hat{G}_{i,t}$, and the mean of the variance due to uncertainty in the estimates for each of those $\hat{G}_{i,t}$ values.

$$Var(\hat{G}_{mean,t}) = \frac{\sum_{i=0}^{n}(\hat{G}_{i,t} - \hat{G}_{mean,t})^2}{n} + \frac{\sum_{i=0}^{n} Var(\hat{G}_{i,t})}{n}$$

In the above equation (*after* Link et al. 1994, p. 1098), the first additive term was the average of the squared differences between each $\hat{G}_{i,t}$value and the mean; this was the sample variance of the mean. The second term was the average of the $Var(\hat{G}_{i,t})$ values from each of the n sampled points for year t; this was the mean of the within-point variance values. We calculated values for $\hat{G}_{mean,t}$ and $Var(\hat{G}_{mean,t})$ using the database query **qs_G_hat_mean** (Figure 4).

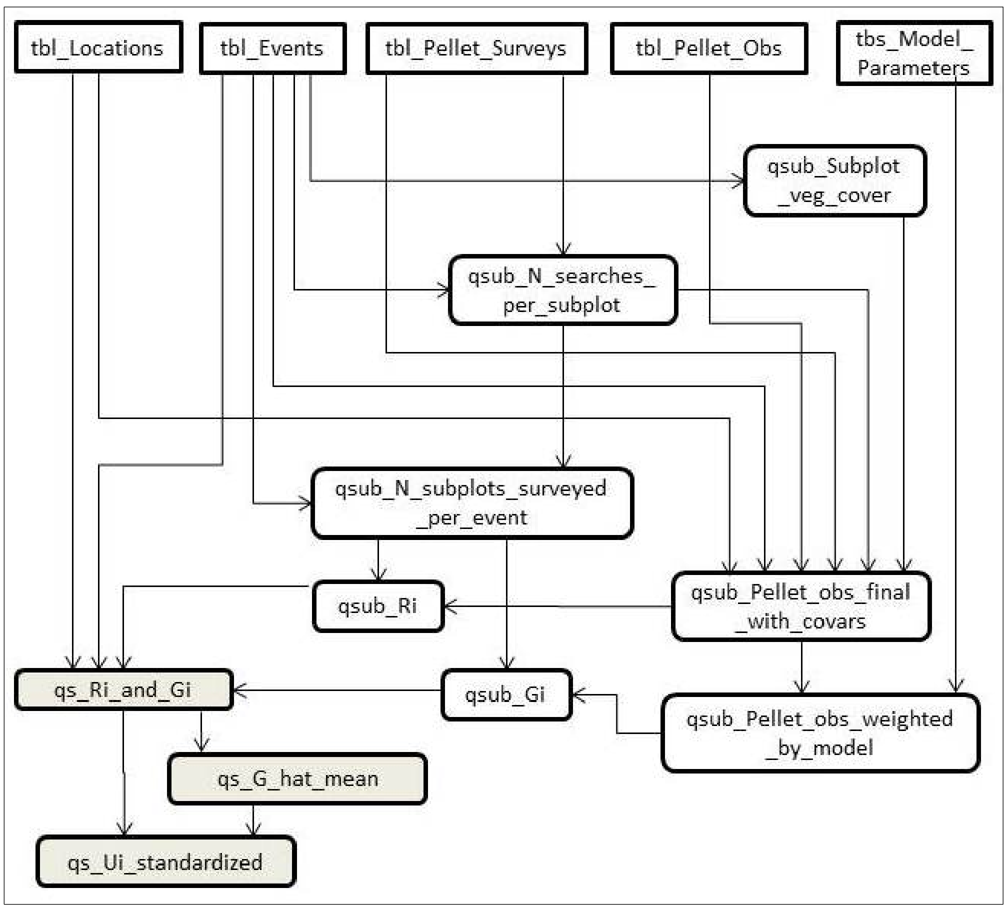

Figure 4. Information flowchart of database tables and queries used to find observed pellet group counts (R_i), estimated pellet group densities (G_i and $\hat{G}_{mean,t}$), and standardized pellet group densities (U_i). The R_i and G_i and U_i values are specific to points, while $\hat{G}_{mean,t}$ is the average pellet group density in the sampled area (note that G_i is written as Gi and $\hat{G}_{mean,t}$ is denoted as G_hat_mean in the database), and standardized value of pellet group density estimated for each sampled point (U_i). In this information flowchart, rectangles indicate database tables (with prefix "tbl_"), while rectangles with rounded corners indicate intermediate subqueries (with prefix "qsub_") and summary queries (with prefix "qs_"). Specific calculations in subqueries and queries are omitted here but are described in the text.

In this report, we present $\hat{G}_{mean,t}$ and $Var(\hat{G}_{mean,t})$ estimates for each of the four years in the 2008-2012 period. For future reference, we recorded estimates of $\hat{G}_{i,t}$ and $Var(\hat{G}_{i,t})$ for each point, and for each year, in the results table of the database, **tbl_Results**, along with estimates of $\hat{G}_{mean,t}$ and $Var(\hat{G}_{mean,t})$.

Trends in Pellet Group Density
We used weighted least squares regression (see below, *Weighted Least Square Regression*) to find the slope of the regression line fit through the $\hat{G}_{mean,t}$ values, where we used the inverse of the variance for each year's point estimate, $Var\left(\hat{G}_{mean,t}\right)$ as weights (Gerrodette 1991).

Spatial Patterns in Pellet Group Density
We interpolated point estimates for $\hat{G}_{i,t}$ across the Fort Clatsop unit, to map the prevalence of elk use across the unit in each year *t*. Interpolation calculates values for locations that were not surveyed, based on weighted contributions from surrounding, surveyed points where values for $\hat{G}_{i,t}$ are estimated. We interpolated using the inverse distance weighting (IDW) method (Shepard 1968), which calculates values for every pixel, *z*, based on the weighted contributions from surrounding points. We followed the equation below, in which the interpolated value for $\hat{G}(z)$ at location *z* is given as a function of the k=12 closest surveyed points.

$$\hat{G}(z) = \frac{\sum_{k=0}^{12} d_k(z)\hat{G}_{i,t}}{\sum_{k=0}^{12} d_k(z)}$$

We used as weights, d_k, for each of the 12 contributing point values, the inverse of the squared distance between the position of pixel *z* and point *i*. The weights in spatial interpolation had no relation to any variance estimate, or to the pellet group correction factors that account for detection bias. For this equation, 250 meters was a 'distance' of one unit – therefore, a surveyed point that was 500 m away from pixel *x* contributed ¼ as much as a surveyed point that was 250 m away. The IDW analysis tool in ArcGIS Spatial Analyst used the $\hat{G}_{i,t}$ values as the *z*-value field of input points with known value. We set the power of the weighting to 2, representing an inverse squared weighting. We used a 50-m cell size, so that interpolated values apply to ¼-ha areas. We used the variable search radius of up to 1000 m, which leads to inclusion for the 12 closest points for which values of $\hat{G}_{i,t}$ are available.

Spatial Trends in Pellet Group Density
Both the magnitude and the spatial distribution of pellet group density may change over time, so to assess changes in the spatial distribution we standardized values of pellet density at each point. We standardized each point's value of $\hat{G}_{i,t}$ for year *t* into a unitless measure of standardized pellet group density, which we denoted as $\hat{U}_{i,t}$, by subtracting the mean pellet group density for year *t*, $\hat{G}_{mean,t}$, and dividing by the standard deviation of the $\hat{G}_{i,t}$ values. Across all sampled points in a given *t* year, the mean value of $\hat{U}_{i,t}$ was always 0, but mapped changes in the spatial distribution of $\hat{U}_{i,t}$ could indicate the positive or negative shifts in the spatial pattern of elk use within the Fort Clatsop unit. We calculated values for $\hat{U}_{i,t}$ for each point and year with the database query **qs_Ui_standardized**.

To visualize changes in spatial distribution, we calculated trends in $\widehat{U}_{i,t}$ over time for each point, then mapped and interpolated the slope of the trends across the Fort Clatsop Unit. We assessed the trend in any change in standardized use at each surveyed point over time using linear regression. At many points we could not weight $\widehat{U}_{i,t}$ values by the inverse of the variance because some of the estimated variance values were zero. Thus, for each pellet survey point, we used unweighted linear regression to find the slope for trends in standardized pellet group density over time and an estimate of the statistical significance of that slope, as measured by the P-value for the 2-tailed test comparing the slope to a null hypothesis value of zero.

We imported values for the estimated slope of the regression line for each point, Slope_U_i into the project geodatabase for interpolation across the Fort Clatsop unit, using the same IDW algorithm as we used for the interpolation of pellet density. Spatial shifts in use appeared as regional increases or decreases in the interpolated surface of Slope_U_i. In assessing unit-wide shifts in spatial distribution of standardized pellet group density, we also considered the statistical significance of the slopes measured at each point.

Proportion of Areas where Elk Pellets Occurred

For each year *t*, we estimated the proportion of areas where elk pellets occurred in the Fort Clatsop unit, $\widehat{PAO}_t$, using single-season occupancy models with heterogeneous detection probabilities (MacKenzie et al. 2006). To estimate $\widehat{PAO}_t$ we also had to estimate a function for the probability that an observer sees any elk pellets, given that there was one or more pellet groups in those subplots to be seen, $\hat{p}_{detection,t}$.

Two observers searched independently for elk pellets in the subplots at each surveyed point. Each observer surveyed three out of the four subplots: two subplots as the first observer, and one as the recount observer. For each observer, detection at a given survey point was a binary outcome – based on all three subplots searched by an observer, that observer either detected or did not detect elk pellets there. We created a database query, **qs_PAO_MARK_prep** (Figure 5), to create tabular data from late winter pellet surveys.

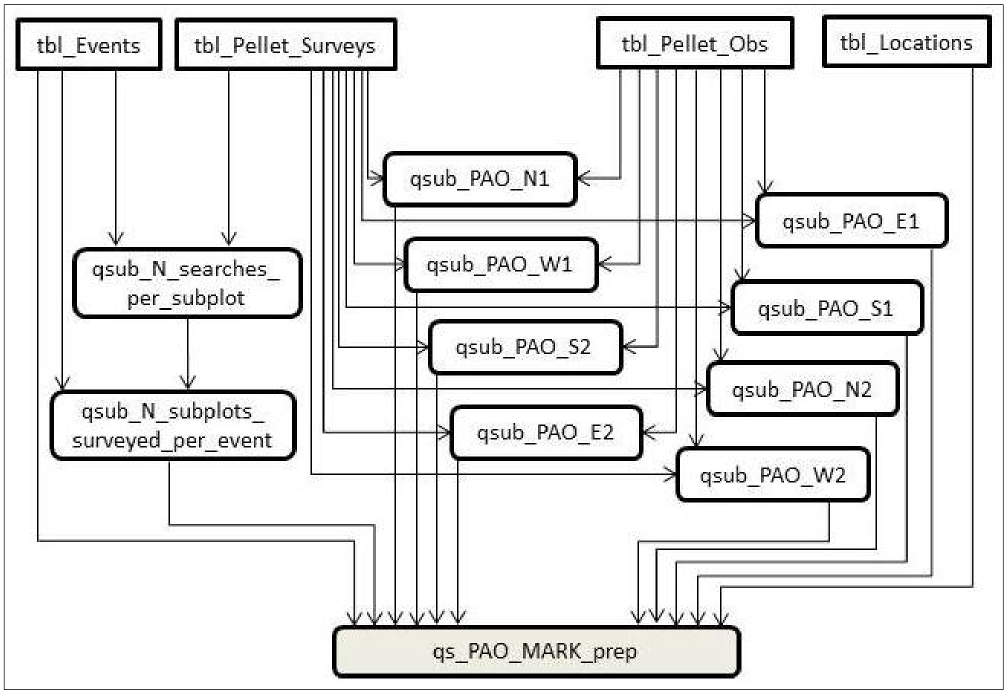

Figure 5. Information flowchart of database tables and queries used to generate the summary query that is used as input for the PAO analysis (qs_PAO_MARK_prep). Subqueries ending in _N1, _W1, _S2, and _E2 are derived from one observer's observations, while subqueries ending in _E1, _S1, _N2, and _W2 come from the other observer's records.

We structured eight occupancy models (Table 2) to account for the possibility that each observer's detection of elk pellets could have been influenced by any of three covariates measured at the 9-m radius plot scale for each point. Those three covariates were 'blowdown,' a bounded continuous measure of the percentage of windthrown trees in the plot, 'light,' a binary variable that contrasts dim light conditions against medium and bright light conditions, and 'effort,' the total number of subplots that were surveyed, ranging from 1 to 4. We fit the models to the data using program MARK (White and Burnham 1999). We modeled each covariate as an additive effect, with no interactions between covariates.

Each of the candidate models in Table 2 led to a single point estimate for $\widehat{PAO}_t$, but the models differ in their estimation of the function for the nuisance parameter, $\hat{p}_{detection,t}$. After model fitting, we found estimates of $\widehat{PAO}_t$ by model-averaging, using the AIC_c weights (Burnham and Anderson 2002). We entered the model-averaged estimates of $\widehat{PAO}_t$ and associated variance estimates in the database table, **tbl_Results**. We examined trends in $\widehat{PAO}_t$ over time using weighted least squares regression (Gerrodette 1991).

Table 2. Candidate set of occupancy models to be fit to one year of observed detection and non-detection data. In model names, PAO(.) indicates that $\widehat{PAO}_t$ will be a single value. The covariates included in parentheses after the "p" are included as additive effects for the function that estimates $\hat{p}_{detection,t}$, except that model PAO(.)p(.) has no covariate that influences $\hat{p}_{detection,t}$. The number of parameters, *k*, is also shown for each model.

Model Number and Name	*k*
1. PAO(.) p(.)	2
2. PAO(.) p(Blowdown)	3
3. PAO(.) p(Light)	3
4. PAO(.) p(Effort)	3
5. PAO(.) p(Blowdown + Light)	4
6. PAO(.) p(Blowdown + Effort)	4
7. PAO(.) p(Light + Effort)	4
8. PAO(.) p(Blowdown + Light +Effort)	5

Testing for Trends with Weighted Least Squares Regression

We used weighted least squares regressions to test for trends in elk pellet group density $\left(\hat{G}_{mean,t}\right)$, the proportion of areas where elk pellets occurred ($\widehat{PAO}_t$), the number of elk groups seen during road surveys, and the total number of elk seen during road surveys. We weighted each point estimate of a value ($\hat{y}_t$) with the inverse of its estimated variance, $Var(\hat{y}_t)$ (Gerrodette 1991). This approach gives more weight to points estimated with greater precision. In Equations below, $\hat{b}$ is the estimated slope of the linear regression, $\hat{a}$ is the estimated intercept, $Var(\hat{b})$ is the estimated variance of the slope, x_t is an integer corresponding to survey year with values of 0, 1, 2, and 3 corresponding to the first, second, third, and fourth years of monitoring (i.e., 2009, 2010, 2011, and 2012), $\hat{y}_t$ is the value for the variable in year *t*, and V_t is the estimated variance for y_t.

$$\hat{b} = \frac{(\sum \frac{1}{V_t} * \sum \frac{x_t * \hat{y}_t}{V_t}) - (\sum \frac{x_t}{V_t} * \sum \frac{\hat{y}_t}{V_t})}{(\sum \frac{1}{V_t} * \sum \frac{{x_t}^2}{V_t}) - (\sum \frac{x_t}{V_t})^2}$$

$$\hat{a} = \frac{(\sum \frac{{x_t}^2}{V_t} * \sum \frac{\hat{y}_t}{V_t}) - (\sum \frac{x_t}{V_t} * \sum \frac{x_t * \hat{y}_t}{V_t})}{(\sum \frac{1}{V_t} * \sum \frac{{x_t}^2}{V_t}) - (\sum \frac{x_t}{V_t})^2}$$

$$Var(\hat{b}) = \frac{\sum\left(\hat{y}_t - \hat{a} - \hat{b} * x_i\right)^2 * \sum \frac{1}{V_t}}{(\sum \frac{1}{V_t} * \sum \frac{{x_t}^2}{V_t}) - (\sum \frac{x_t}{V_t})^2}$$

We evaluated the significance of the slope against the null hypothesis of slope equal to zero using a two-tailed test. To determine the P-value for the test, we calculated the test statistic, T, as the estimated slope ($\hat{b}$) divided by the estimated standard error of slope (SE($\hat{b}$)), which SE is the square root of $Var(\hat{b})$. We evaluated this quantity [T = ($\hat{b}$)/SE($\hat{b}$)] against the students-t score, given n-2 degrees of freedom, where n is the number of years with an estimate. For this analysis, d.f. = 2, SE($\hat{b}$) was the square root of $Var(\hat{b})$, and the nominal type one error rate (α) was 0.10.

We conducted simulations to determine the approximate number of additional years that would be necessary to find statistically significant levels of change for elk pellet density and PAO, given the patterns observed in the first four years of monitoring. For these simulations, we assumed that the slope and variances calculated from the first four years of data will remain constant in the near future. We projected $\hat{y}_t$ for future years by adding or subtracting a random number from a uniform distribution with mean equal to the mean of the observed residuals from the first four years of monitoring.

Road Surveys

Sampling Design

We surveyed the numbers of elk groups, total numbers of elk, and the sex and age composition of elk observed along 4 vehicular survey routes in and adjacent to the Fort Clatsop unit (Figure 6). We selected the 4 survey routes based on their proximity to the Fort Clatsop unit, vistas of open landscapes, public access, and safety (Figure 6). We limited inferences from these road surveys to areas that were directly visible from the roads sampled because the selection of those roads and their placement in the landscape was neither random nor systematic.

Starting in December 2008, we conducted road surveys during February, April, June, August, October, and December, with at least three surveys per month. We separated sequential surveys by at least four days to reduce temporal autocorrelation. Additional months of survey data were collected in 2008 and 2009 but were not included in trend analysis due to insufficient sample size. All four survey routes were surveyed successively within a single morning, with the order of routes surveyed varying between survey events. For trend analyses, the four routes surveyed in a single morning were pooled to constitute a single replicate survey.

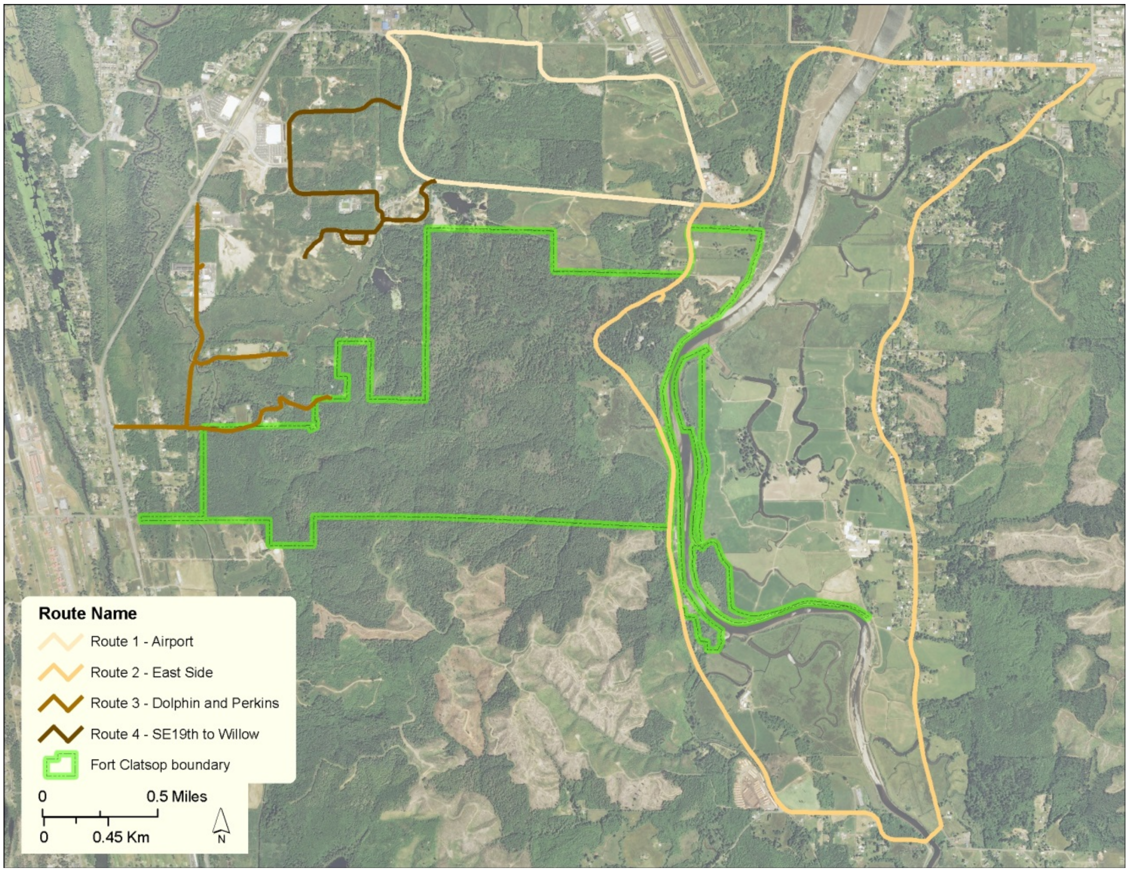

Figure 6. Four road survey routes for elk in the vicinity of the Fort Clatsop unit. The Clatsop Plains includes areas to the north, west, and southwest of the unit. Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture).

Field Methods

Two-person survey crews (driver and observer) started surveys no later than 15 minutes after sunrise and typically finished within 2 hours after sunrise. Before initiating the survey, the observers recorded weather conditions. Road surveys were conducted unless precluded by high winds, heavy rain, sleet, snow, dense fog, or hail.

All surveys were conducted from a park vehicle. Specified routes were driven slowly – between 15 and 25 mph. After completing one route, the driver proceeded to another, until all four routes were surveyed and the survey was completed. When an elk group (one or more elk) was seen, the driver pulled off the road. Both the driver and observer counted the total number of elk, and numbers of calves (young of the year born in June), antlerless elk, and antlered elk (bulls). We classified adult elk as ‘antlered’ or ‘antlerless’ because it was not always possible to unambiguously classify elk as bulls or cows from a distance after bull elk had dropped their antlers during winter. Observers recorded locations of each observation by recording the UTM coordinates of the vehicle using a handheld GPS unit, or by recording the miles and tenths of miles along the route closest to their parked location (every tenth of a mile section has an associated set of UTM coordinates in the project database; see Figures 7-10). The observer then used a laser range finder to record the distance to the center of the elk group, and used a sighting compass to record the compass bearing (azimuth) from observer to elk group. Distances and azimuths were recorded so that the locations where animals were seen could be mapped.

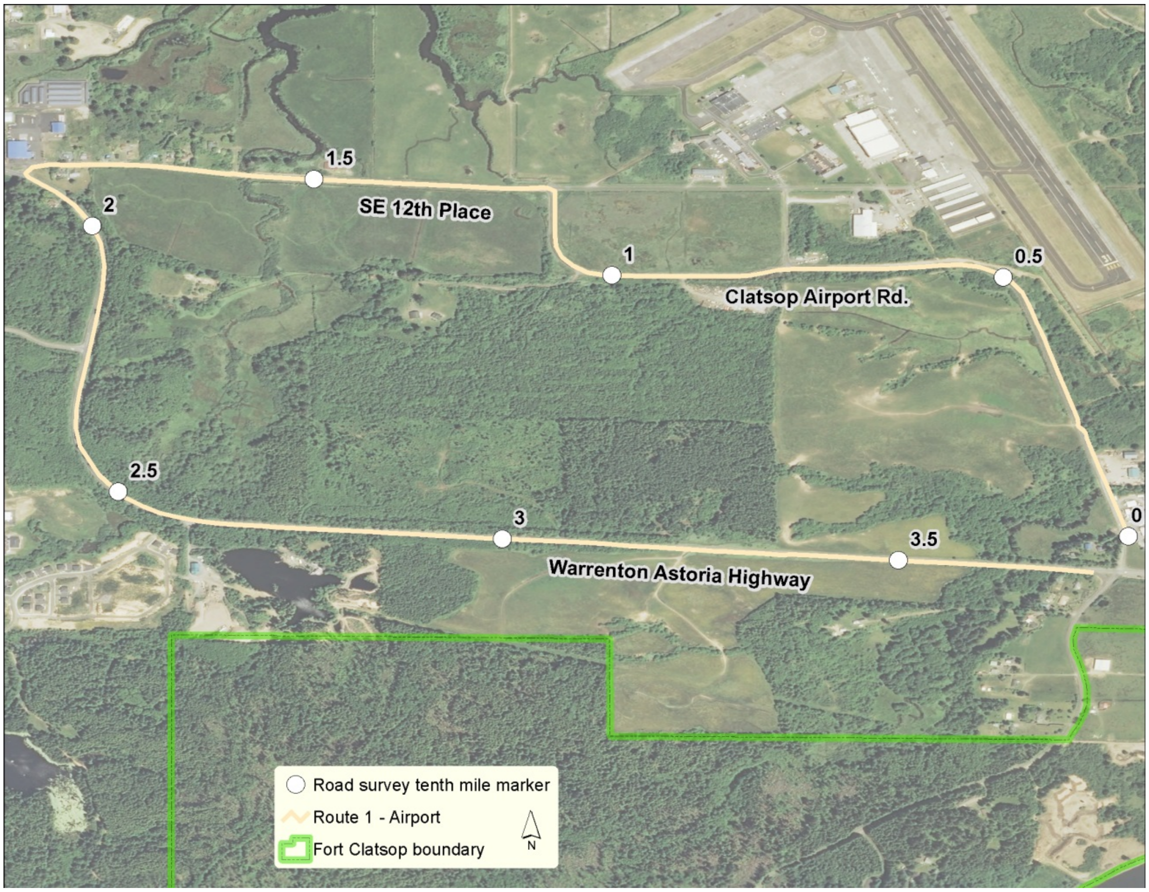

Figure 7. Elk Road Survey Route 1 (Airport). Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture). Circles indicate distances, in miles, from the start point.

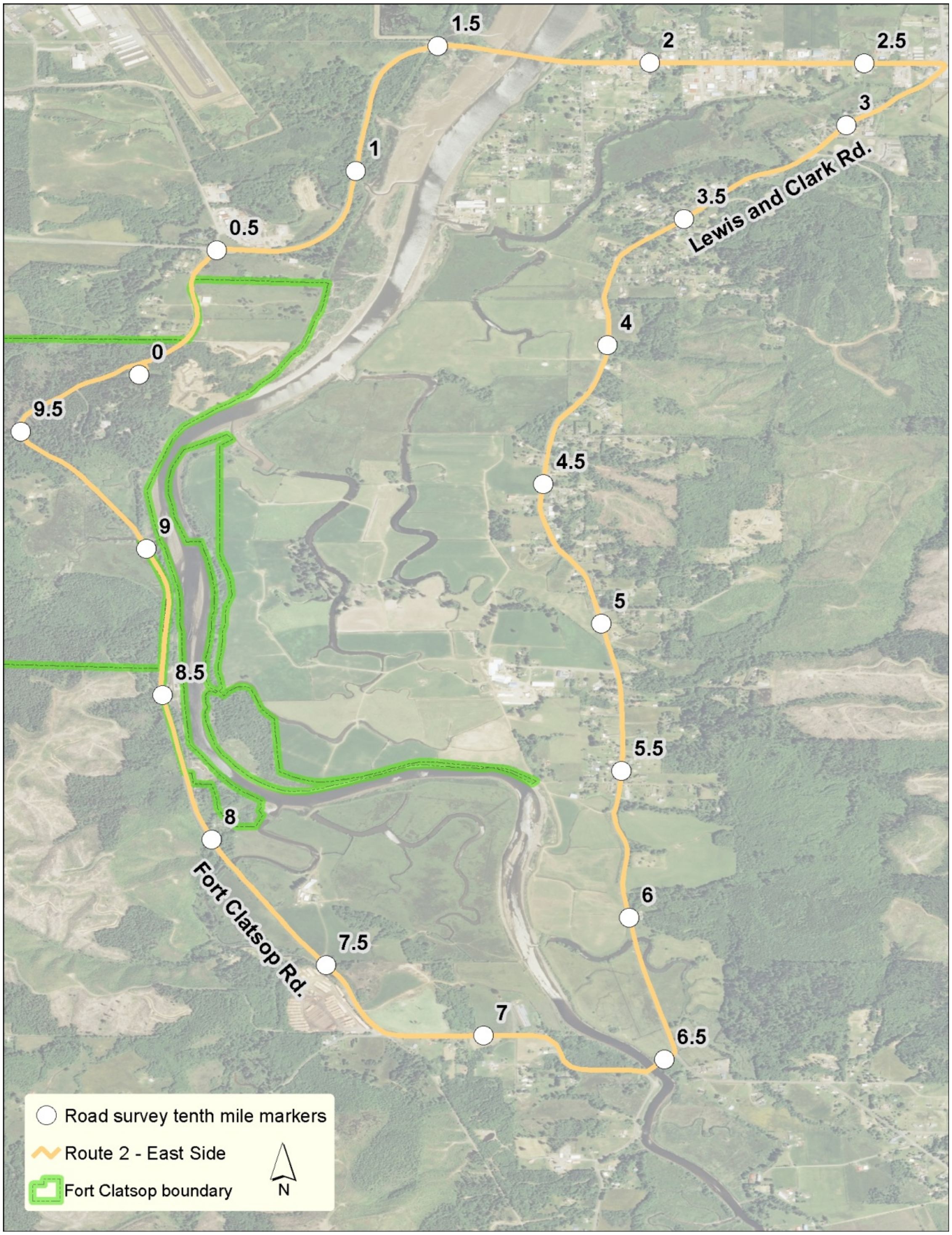

Figure 8. Elk Road Survey Route 2 (East Side). Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture). Circles indicate distances, in miles, from the start point.

Figure 9. Elk Road Survey Route 3 (Dolphin and Perkins). Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture). Circles indicate distances, in miles, from the start point.

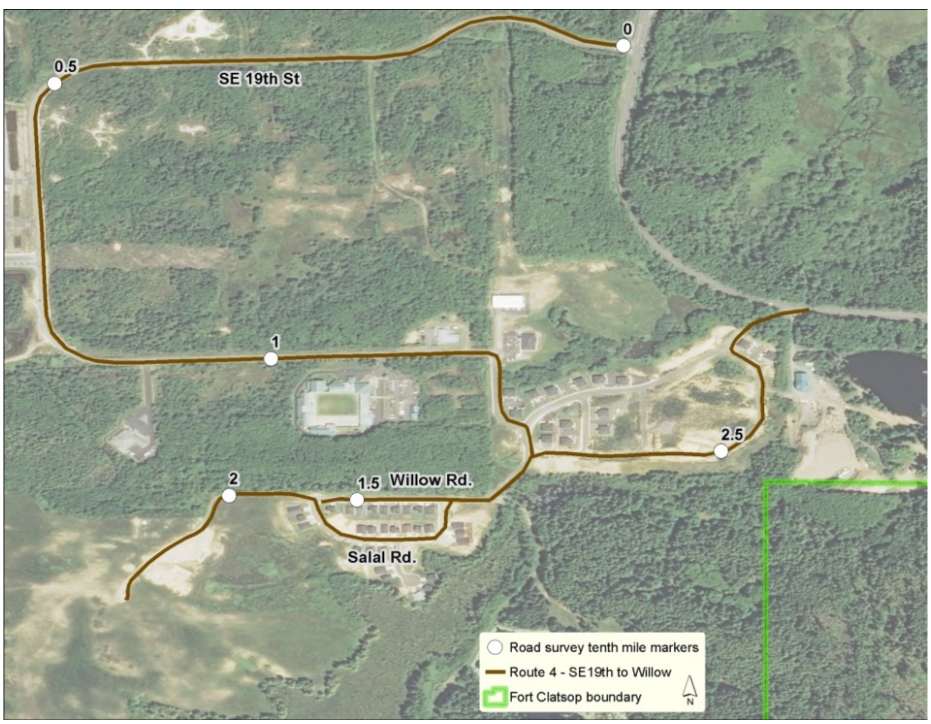

Figure 10. Elk Road Survey Route 4 (SE 19th to Willow). Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture). Circles indicate distances, in miles, from the start point.

Data Analysis

We pooled results from all four survey routes conducted on the same morning to comprise a single survey for the analysis of trends. For analyses of means and trends, we did not use data recorded from October 2008, or from the months for which road surveys were discontinued after 2009 (January, March, May, July, September, and November). For each month, we computed the arithmetic mean (average) and variance of the number of elk groups seen per survey, and the total number of elk seen per survey.

For analyses of monthly trends in the number of elk groups seen during road surveys, and total numbers of elk seen during road surveys, we tested for the significance of trends using regression weighted by the inverse of variance (Gerrodette 1991). For these tests, though, we maintained the experiment-wide error rate of α=0.10 using Bonferroni adjustments (Rice 1989) for comparing trends within the six individual months for which trend estimation was possible. For those two measures the P-value necessary to conclude a significant trend in any single month was 0.017. We included data from October 2012 in trend analyses in order to have 4 years of data from each of the months in which we examined trends.

We computed the ratio of observed calf:antlerless adult elk ratio and the observed antlered:antlerless adult elk ratio by month. Because male elk shed antlers during winter and may be misclassified as females, and because calves are hard to distinguish from yearlings as they age, we examined trends in the calf:antlerless adult ratio and the antlered:antlerless adult ratio during June, August, October, and December only. In testing for trends in these composition ratios, no measure of variance was available, so we used ordinary least squares linear regression. In testing for a temporal trend for each month, we maintained the experiment-wide Type I error rate of α=0.10 using Bonferroni adjustments (Rice 1989). As a result, for composition ratios the P-value necessary to conclude a significant trend in any single month was 0.025.

To provide a baseline for future comparisons of changes in spatial distributions of elk sightings along survey routes, we mapped all locations where elk groups were seen in road surveys. For each elk group observed during road surveys, the database query **qs_Elk_group_locations** (Figure 11) returned the date, group size, sex and age composition, and the estimated UTM coordinates for the group location. We grouped the mapped observations according to three four-month periods: October 1 – January 31, February 1 – May 31, and June 1 – September 30. We included observations recorded between November 2008 and September 2012.

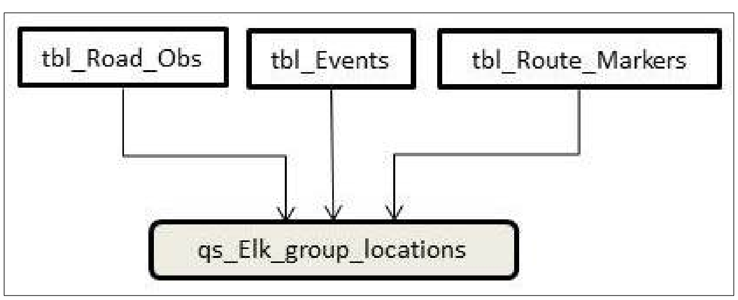

Figure 11. Information flowchart of database tables and queries used to generate the query (qs_Elk_group_locations) that calculates UTM coordinates for elk groups observed during road surveys.

Results

Sampled Points

We surveyed elk pellets at all safely accessible points that were not prone to submersion under water. The fall 2008 pellet clearing session was the most labor-intensive survey because we visited nearly every numbered point to assess the feasibility of access. In the late winter pellet counting session in 2009 we surveyed 61 points (Figure 12). In fall 2009 we visited some points that were previously considered too steep based on an erroneous GIS layer, and added a subset of those points to the survey set. As a result, in the late winter session in 2010 we surveyed 66 points. In late winter sessions in 2011 and 2012, we surveyed 64 and 65 pellet points, respectively. At least one group of elk pellets was detected at 27 points in 2009 (44%), 30 in 2010 (45%), 23 in 2011 (36%), and 25 (38%) in 2012.

Figure 12. Maps of late winter pellet survey results from 2009, 2010, 2011, and 2012. Green triangles indicate that one or more pellet group was found during survey, orange triangles indicate that no pellet groups were found during survey, and red triangles symbols indicate that the point was not surveyed.

Pellet Group Density

We detected a total of 319 pellet groups during fall clearing sessions (2008-2010) and late winter surveys (2009-2012) that were used in developing double-observer detection probability models. Each pellet group was detected by at least one of two observers. There was reasonable support for four of the 15 candidate detection probability models, based on AIC_c values < 4.0 (Table 3). We model-averaged parameter estimates for those four models to estimate pellet group detection probabilities for each observed pellet group, j ($\hat{p}_{group,j}$), associated correction factors, variance, and estimates of $\bar{\bar{\hat{G}}}_{i,t}$ (pellet group density for each point, i, and year, t).

Table 3. Rankings of 15 candidate models that describe the probability that a given elk pellet group will be detected. Each model is numbered according to model definitions from the protocol (Griffin et al. 2011). Model AIC_c weight is a measure of the relative weight of evidence for that model, given the data and the set of models considered. Models at the top of the list are the most parsimonious; models are ranked from high to low, based on ΔAIC_c values). The number of parameters in each model is listed as *k*. Models with AIC_c < 4.0, shown in bold, were used in model averaging.

Model Number in Protocol and Name		ΔAICc	AIC weight	*k*
8.	**p(ln(Group_size) + Decayed)**	**0.00**	**0.48**	**3**
13.	**p(ln(Group_size) + Light + Decayed)**	**1.11**	**0.28**	**4**
15.	**p(ln(Group_size) + Cover + Light + Decayed)**	**3.11**	**0.10**	**5**
2.	**p(ln(Group_size))**	**3.90**	**0.07**	**2**
7.	p(ln(Group_size) + Light)	5.60	0.03	3
6.	p(ln(Group_size) + Cover)	5.90	0.03	3
12.	p(ln(Group_size) + Cover + Light)	7.62	0.01	4
5.	p(Decayed)	78.30	0.00	2
11.	p(Light + Decayed)	80.16	0.00	3
10.	p(Cover + Decayed)	80.27	0.00	3
14.	p(Cover + Light + Decayed)	82.12	0.00	4
1.	p(.)	90.74	0.00	1
3.	p(Cover)	92.69	0.00	2
4.	p(Light)	92.69	0.00	2
9.	p(Cover + Light)	94.64	0.00	3

Each model included coefficients for β parameters corresponding to the model intercept, and effects of the covariates ln(group_size), cover, light, and decayed. We entered β parameter values and associated variance-covariance matrix values in the **tbs_Model_parameters** table. For models lacking a given covariate's effect, we assigned values of zero for that β parameter.

The per-observer detection probability ($\hat{p}_{group,j}$) was affected most by ln(group_size) and was less affected by decay class and lighting conditions (Figure 13). Per-observer detection probabilities ranged from as low as ~10-15% for single pellets to ~85-90% for pellet groups with 50 pellets (Figure 13). Decayed pellet groups were generally about 4-8% less likely to be detected by a given observer depending upon pellet group size and lighting conditions (Figure 13). Lighting conditions and cover had only negligible influence on detection probabilities. The relative unimportance of cover class may be partly explained by the fact that vegetative cover was measured as a single value for the entire subplot, and did not accurately reflect sighting conditions for specific pellet groups.

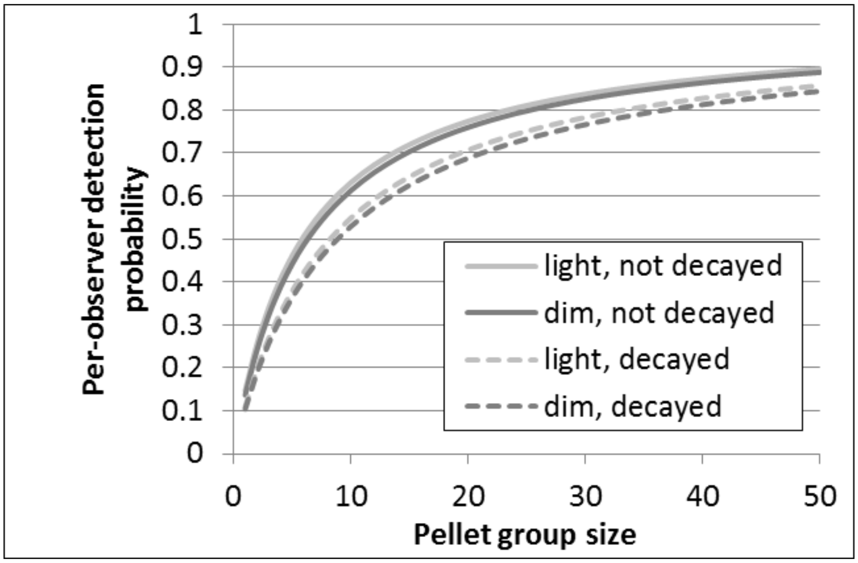

Figure 13. Per-observer expected elk group pellet detection probabilities, shown as a function of the covariates group size (x-axis), light, and pellet decay class. Curves for pellet groups viewed in dim conditions are shown with dashed lines, and pellet groups in medium or bright light are shown with solid lines. All curves assume 50% vegetative cover in the subplot.

The number of observers inspecting a given subplot had a large effect on the expected detection probabilities, the associated correction factors ($\hat{w}_{j1}$ or $\hat{w}_{j2}$) (Figure 14A), and on the variance of the estimated correction factors. Detection probabilities were higher and correction factors lower for pellet groups found in subplots surveyed by two observers than in subplots searched by only one observer (Figure 14A). The difference in correction factors $\hat{w}_{j1}$ or $\hat{w}_{j2}$ decreased substantially as pellet group size increases, because large pellet groups are likely to be detected by both of the observers. Standard errors of the correction factors were greatest for small pellet groups, particularly in subplots searched by one observer only (Figure 14B).

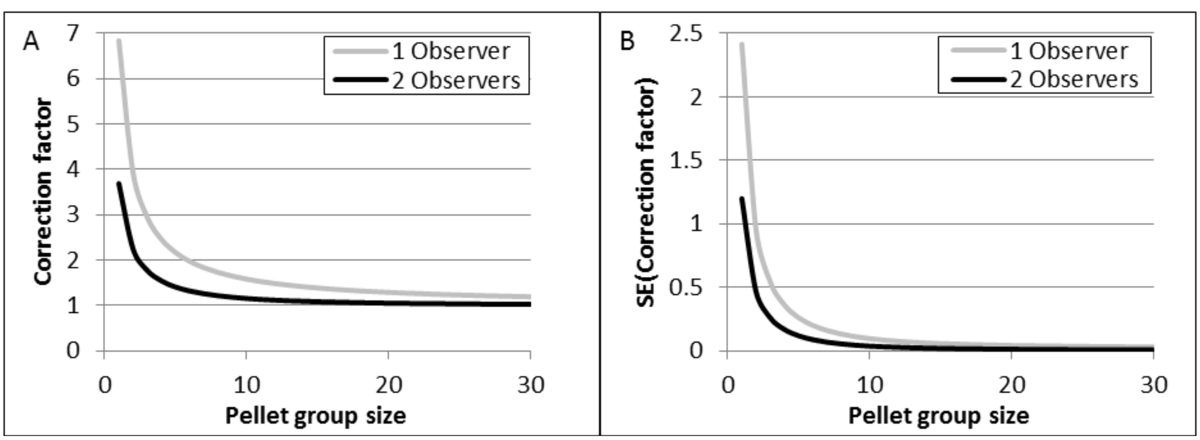

Figure 14. Correction factors and standard errors (SE) of correction factors used to adjust raw pellet group counts and reduce detection biases. Correction factors are in A (at left) and SE of correction factors are in B (at right), both shown as functions of pellet group size (x-axis) and 1 versus 2 observers. The grey curve is for pellet groups in subplots searched by only one observer, [$\hat{w}_{j1}$ and SE($\hat{w}_{j1}$)]. The black curve is for pellet groups searched by two observers [$\hat{w}_{j2}$ and SE($\hat{w}_{j2}$)]. All curves are based on vegetative cover of 50%, good lighting conditions and pellet decay class $\leq$3.

After completing the analysis of *a priori* models of pellet detection probabilities, we evaluated whether or not observer experience also may have affected pellet detection probabilities measurably. Although it was not feasible to model the effects of individual observers on detection probabilities, we examined the effects of two measures of observer experience: (1) whether or not the observer was a resource professional involved in the protocol implementation (i.e., from Lewis and Clark NHP Resources Management Division, NCCN I&M program, or USGS), or (2) whether the observer had conducted pellet group surveys previously (i.e., experienced versus novice). To examine these two possible effects we structured two *a posteriori* models that included covariates from the top-ranked *a priori* model (model 8: ln(Group_size + Decayed) as well as one of the measures of observer experience. In *a posteriori* model 16 [p(ln(Group_size) + Decayed + Resource)], the 'resource' covariate reflected whether or not the observer was from a resource-related work unit. In *a posteriori* model 17 [p(ln(Group_size) + Decayed + Experience)], the 'experience' covariate indicated whether observers had already surveyed for pellets in one or more previous survey sessions. AIC_c values for both models were greater (less informative) than model 8; model 17 had Δ AIC_c=1.26 and model 16 had Δ AIC_c=1.96. The higher-ranked of the two, model 17, led to expectations that experience did improve detection probability; the degree of improvement was slight though, and the standard error was larger than the estimated effect of experience. Thus, while model 17 indicated that experience could have a small effect on pellet group detection probability, we cannot yet accurately parameterize the effect of this experience. At this time we conclude that neither of the *a posteriori* covariates improved model fit or interpretation to the extent that we would advocate including them in model-averaged inferences about pellet group density, along with the *a priori* models. We would, however, suggest that the 'experience' covariate be included in models in the a priori model set considered in the next 4-year synthesis.

Trend in mean pellet group density

Mean estimated annual densities of pellet groups, $\widehat{G}_{mean,t}$, varied from 0.579-0.932 pellet groups per subplot from 2009-2012 (Table 4). These mean estimated densities are more than twice the raw (uncorrected) average numbers of pellet groups per subplot ($R_{mean,t}$).The estimated slope of the weighted regression line (Figure 15) for pellet group density, $\hat{b}$, was -0.0876 (SE($\hat{b}$) = 0.0401). This slope was not significantly different from zero ($\frac{\hat{b}}{SE(\hat{b})}$ = 2.1834, df = 2, 2-tail Students-t P = 0.1606).

Table 4. Estimated mean pellet group density per subplot in the Fort Clatsop unit by year *t* ($\overline{\overline{G}}_{mean,t}$) and estimated standard error [SE($\overline{\overline{G}}_{mean,t}$)]. Subplots were 3-m in radius. For comparison, the raw (uncorrected) average number of pellet groups per subplot ($R_{mean,t}$) is also shown.

Survey Session	$\widehat{G}_{mean,t}$.	SE($\widehat{G}_{mean,t}$)	$R_{mean,t}$
Late winter 2009	0.932	2.252	0.447
Late winter 2010	0.668	1.374	0.333
Late winter 2011	0.589	1.434	0.263
Late winter 2012	0.579	1.245	0.258

When we used Monte Carlo simulations to simulate future values of $\widehat{G}_{mean,t}$, the simulated decline was statistically significant by 2014 in >70% of simulations, and was statistically significant by 2015 in >95% of simulations.

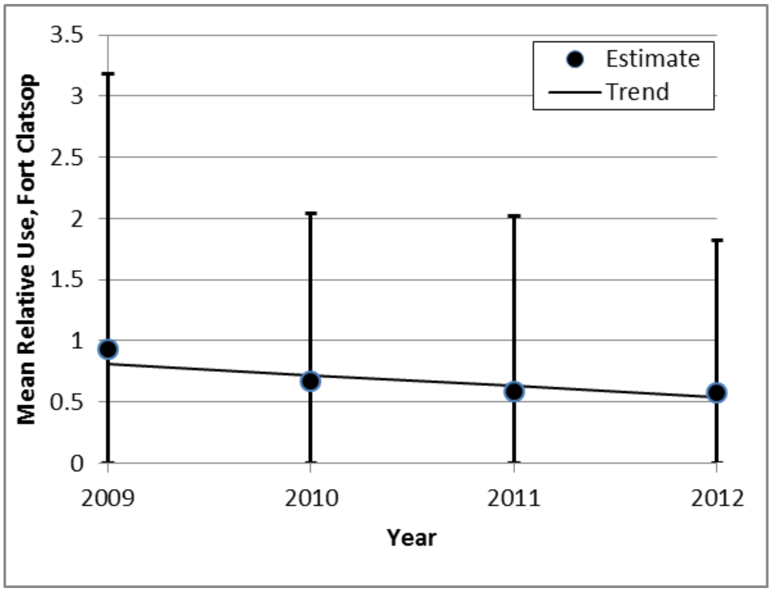

Figure 15. Estimated mean elk pellet group density per 3-m radius subplot ($\hat{G}_{mean,t}$) and regression trend line at the Fort Clatsop unit of Lewis and Clark NHP, 2009-2012. The trend line (slope = -0.0876, SE=0.0401) was fitted using weighted linear least squares regression. Error bars around each point are + / - 1 standard error.

Six points from the systematic sample frame were first surveyed in 2010 because we discovered they were previously deleted from the sample for safety reasons that turned out not to be of concern. In a post-hoc exploratory analysis, we assessed what would be the effect of excluding those six points from temporal trend estimation for the Fort Clatsop unit, to examine whether the observed decrease in pellet density over time may be related to the addition of points in 2010. The apparent decrease was qualitatively the same whether or not the six points were included in analyses.

In another post-hoc analysis, we assessed the pellet group density trend exclusively for 13 points that the NCCN Vegetation Mapping Project (Catherine Copass, NPS, NCCN, unpublished spatial data) indicated were in the ‘disturbed forest’ type (n=11), or where survey crew had repeatedly recorded blowdown severity of 75-100% (n=2). This analysis examined whether trends in pellet density in areas of severe blowdown varied from the overall trend. Pellet group density as measured by $\hat{G}_{i,t}$ decreased over time at six of the points and increased over time at two of the points; no elk pellet groups were found at five of the points. Because of the limited sample size, we do not put too much value on this trend estimate but the observed linear regression for $\bar{\hat{G}}_{i,t}$ (weighted by the inverse of variance) for these points suggested a decline similar to the overall observed decline(slope = -0.007 per year, SE=0.0009).

Trends in spatial distribution of pellet densities

The spatial patterns of elk pellet group density varied from late winter 2009 through late winter 2012 (Figure 16). In general, pellet group densities were greatest in the southeast part of the Fort Clatsop unit, although spatial differences in use varied among years (Figure 16). Although less pronounced than in the southeast, pellet group density also tended to be above average in the north-central area of the Fort Clatsop Unit.

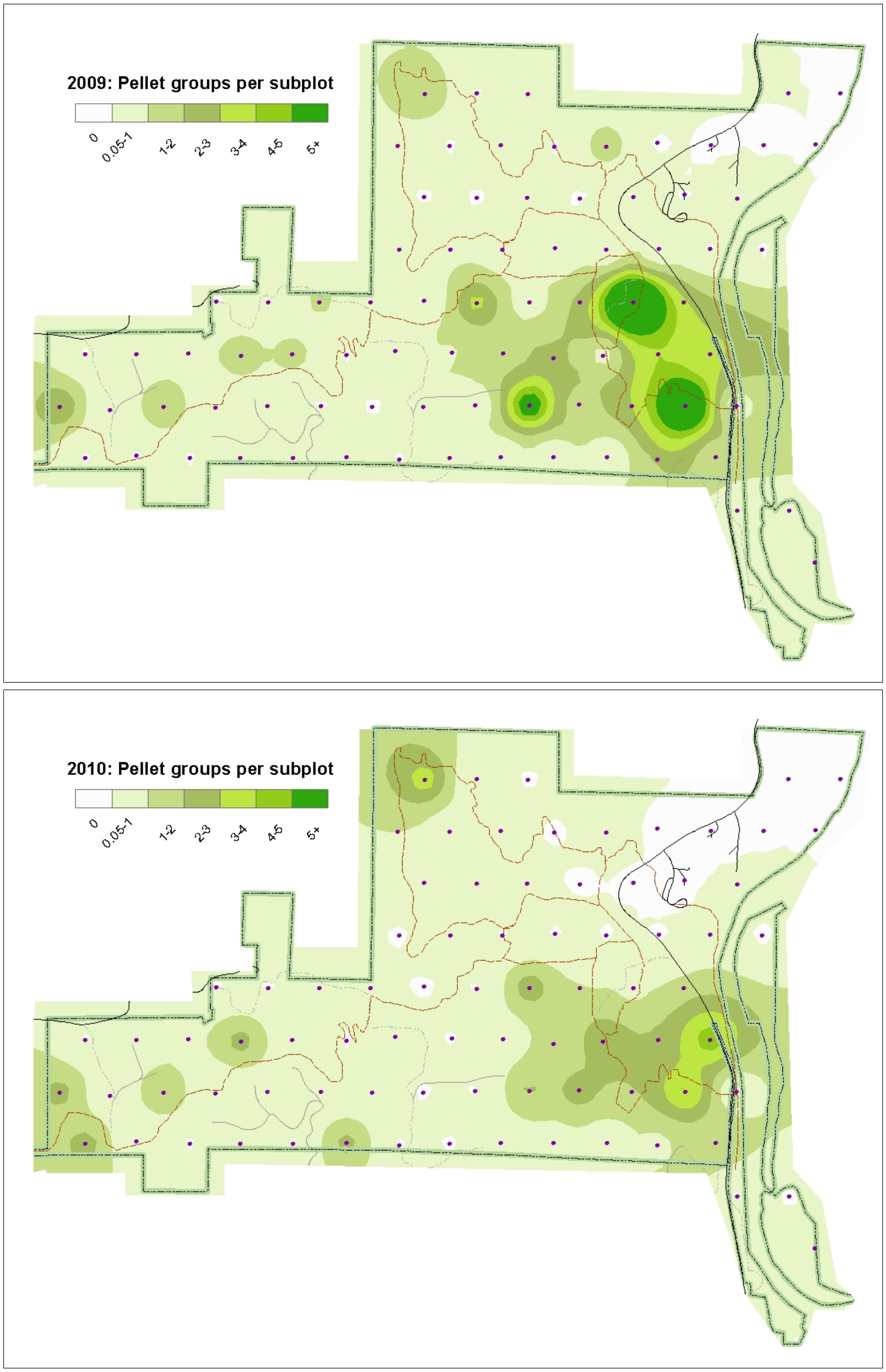

Figure 16. Interpolated pellet group densities, $\hat{\mathbf{G}}$(z) in the Fort Clatsop unit, for late winter 2009, 2010, 2011, and 2012. Interpolations are based on point estimates of pellet group density, $\hat{G}_{i,t}$. The intensity of green color is a measure of the interpolated $\hat{\mathbf{G}}$(z) values. Units are number of pellet groups per 3-m radius subplot. Roads are shown as black lines, and trails as dashed brown lines.

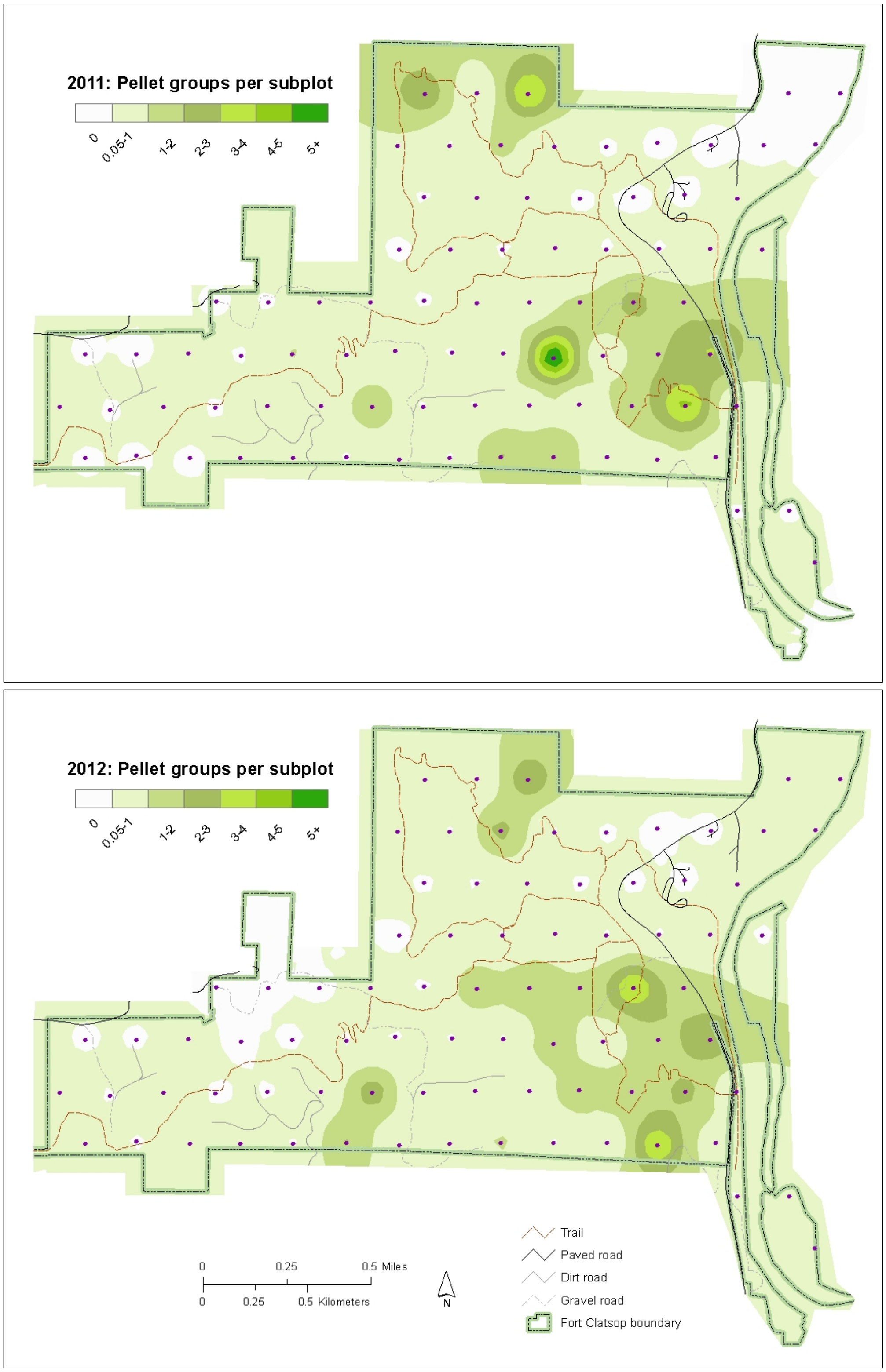

Figure 16. Interpolated pellet group densities, $\widehat{\mathbf{G}}$(z) in the Fort Clatsop unit, for late winter 2009, 2010, 2011, and 2012. Interpolations are based on point estimates of pellet group density, $\hat{G}_{i,t}$. The intensity of green color is a measure of the interpolated $\widehat{\mathbf{G}}$(z) values. Units are number of pellet groups per 3-m radius subplot. Roads are shown as black lines, and trails as dashed brown lines (continued).

We also computed the standardized pellet group density scores, $\widehat{U}_{i,t}$, by subtracting the average value for each year, $\widehat{\mathrm{G}}_{\mathrm{mean,t}}$, from point-specific values for pellet group density, and dividing by the width of the standard deviation for $\widehat{\mathrm{G}}_{\mathrm{mean,t}}$. Because the mean value of standardized pellet group density is always zero within a year, the average value of $\widehat{U}_i$ at a given point for a given year is a measure of the average number of standard deviations above or below the mean value of elk pellet group density at the sampled points. The map illustrating the spatial distribution of this average standardized pellet group density (Figure 17) indicates which points tended to have values greater or less than the mean. The four points where the average standardized pellet group density was more than one standard deviation above the mean (larger circles) were all in the southeast quadrant of the unit, in a variety of habitats (pasture, Sitka spruce upland forest, freshwater marsh, and alder upland forest, respectively), with reference to results of the NCCN Vegetation Mapping project (Catherine Copass, NPS, NCCN, unpublished spatial data).

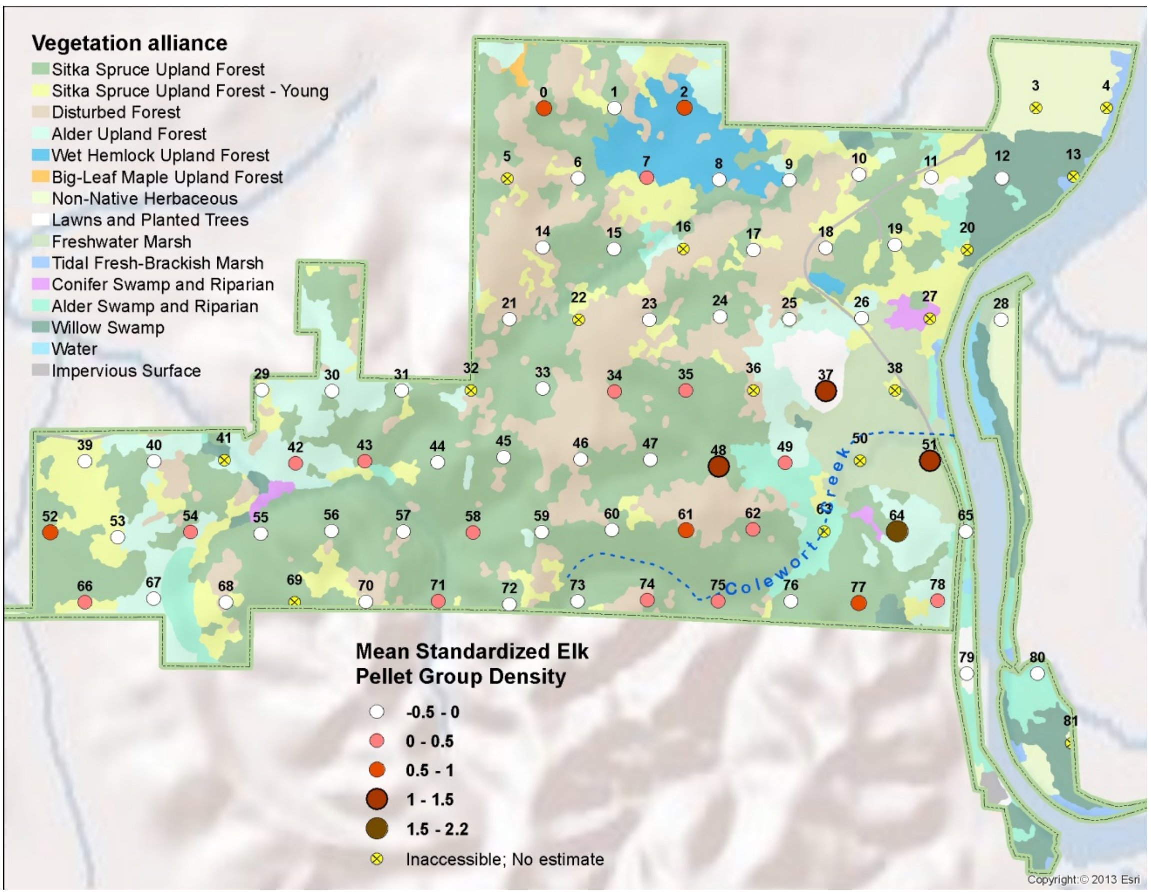

Figure 17. Mean standardized pellet group densities ($\widehat{U}_i$) at sampled points in the Fort Clatsop unit, late winter 2009-2012. Values are shown only for points sampled more than one year. Circle size and color indicate the number of standard deviations above or below the mean (zero) at the point, on average. The background map includes vegetation associations (NCCN Vegetation Mapping project, Catherine Copass, unpublished data) and topography (ESRI, Redlands, California). There is no mean shown for points with poor site access because they were not sampled more than once.

The map depicting temporal trends in standardized elk pellet group density (Figure 18) accounts for year-to-year changes in $\widehat{\mathrm{G}}_{\mathrm{mean,t}}$. Over the four-year period from 2009-2012, standardized elk pellet group density declined significantly at two points (shown in red in Figure 18), and increased significantly at two others (shown in green in Figure 18) (P<0.1, two-tailed). If results from the pellet group density index are an accurate reflection of apparent changes in spatial distribution of elk relative use, they would suggest that use decreased in some parts of the southeast region of the Fort Clatsop unit, with a concomitant increase at other areas such as in the south-central and north-central areas of the unit.

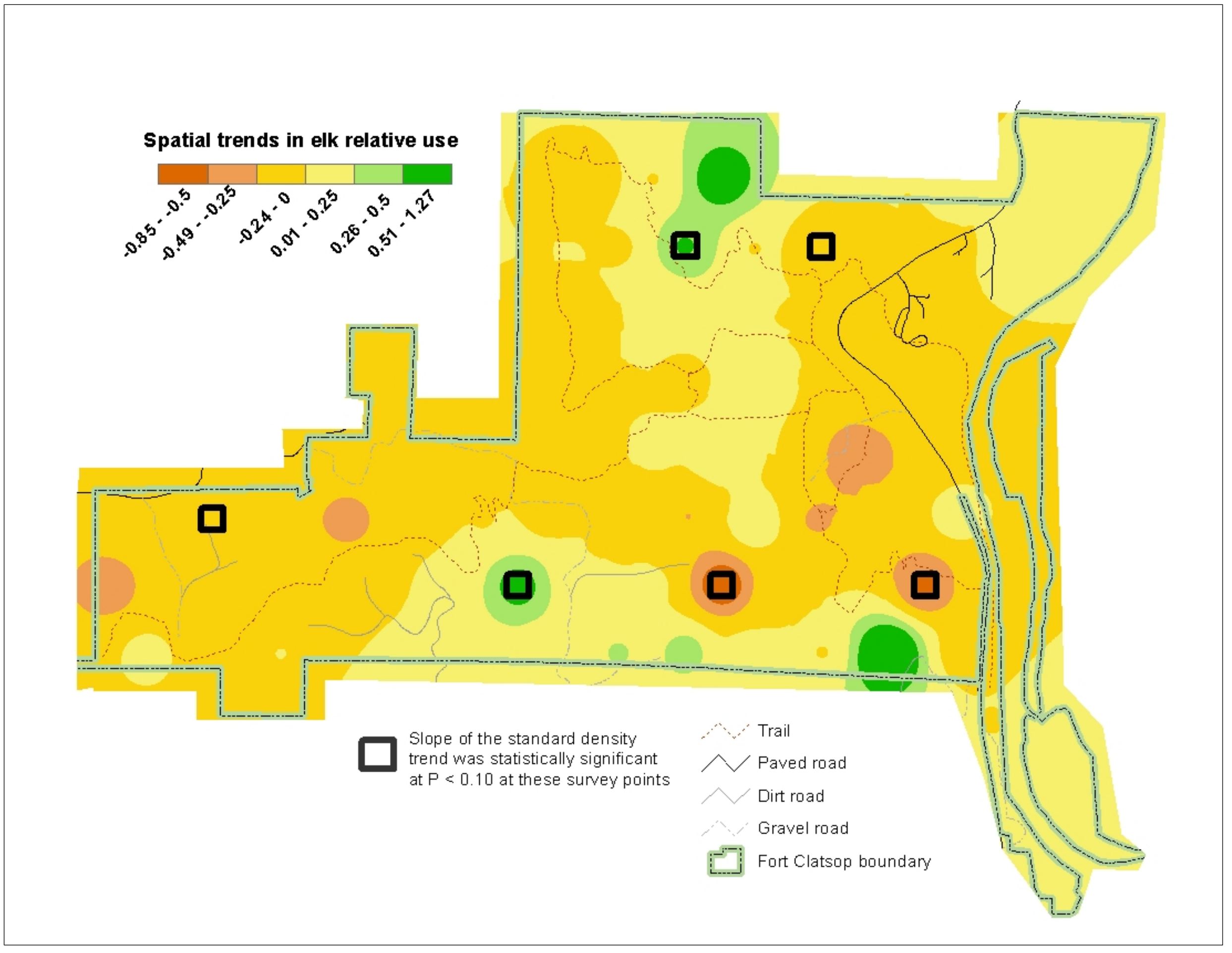

Figure 18. Map of temporal trends in standardized elk pellet group density (U) across the Fort Clatsop unit from 2009-2012.The colored slope values represent the estimated positive or negative change over time in the standardized values of estimated pellet group density at that location; these values are based on interpolation from slopes determined at sampled pellet survey points. Open squares indicate sampled points where the slope of the regression was significantly different than zero (P <0.1, 2-tailed).

Proportion of Areas where Elk Pellets Occurred

Rankings of occupancy models developed to estimate $\widehat{PAO}_t$ varied annually (Table 5). There was no consistent support for the effect of light, blowdown, or effort on the observers' ability to detect elk pellets; these variables, however, were all included in models that had reasonable support (AIC_c<4.0).

Table 5. Relative Akaike's Information Criterion (AIC_c) values among candidate models for proportion of areas where elk pellets occurred (PAO), by year, for Fort Clatsop unit of Lewis and Clark NHP, 2009-2012. AIC_c values indicate overall fit to the observed data, and the difference in AIC_c value from the top-ranked model in each year (ΔAIC_c) is used to rank models. Columns under each year's heading list the ΔAIC_c values for the model in each row. Within each year, the highest ranked model is the one with the ΔAIC_c score of zero; low ΔAIC_c values indicate a more parsimonious fit to the data than higher ΔAIC_c values. Model numbers and names are taken from Table 1. *k* is the number of model parameters.

Model Numbers	*k*	2009	2010	2011	2012
1. PAO(.) p(.)	2	2.5748	9.3056	0	0
2. PAO(.) p(Blowdown)	3	4.2182	5.4391	1.738	0.8501
3. PAO(.) p(Light)	2	0	3.6257	0.6825	0.5611
4. PAO(.) p(Effort)	3	0.8832	6.4331	1.8236	0[a]
5. PAO(.) p(Blowdown + Light)	3	1.6129	2.0652	2.6837	1.9253
6. PAO(.) p(Blowdown + Effort)	4	2.6911	0.5137	3.4304	0.8501
7. PAO(.) p(Light + Effort)	4	0.4087	0	0.1647	0.5611
8. PAO(.) p(Blowdown + Light + Effort)	5	2.2819	0.8472	4.5918	1.9253

[a] Model 4 is essentially equivalent to Model 1 in 2012 because there was no variation in effort (i.e., the number of subplots surveyed per plot); in 2009, 2010, and 2011, fewer than 4 subplots were surveyed at 3, 4, and 4 points, respectively.

Model-averaged estimates of $\widehat{PAO}_t$ ranged from 0.44 (+/- 0.07 SE) to 0.52 (+/- 0.07 SE) annually (Table 6). $\widehat{PAO}_t$ tended to decline during the 4 years, although the trend was not significant (Figure 19). The slope of the weighted regression line for these points was -0.026 per year (SE=0.012), but this slope was not statistically different from zero (2-tailed $\frac{\hat{b}}{\mathrm{SE}(\hat{b})}$=2.13, df=2, 2-tail Students-t P=0.17). The estimated intercept was 0.52. Model-averaged estimates of per-observer detection rate also varied from year to year, with lowest detection rates in the first year of surveys.

When we simulated future values of $\widehat{\mathrm{PAO}}_{\mathrm{t}}$ by randomly varying values around the same regression line, the simulated decline was statistically significant by 2014 in >70% of simulations, and was statistically significant by 2015 in >98% of simulations.

Table 6. Number of plots where elk pellets were observed, versus the estimated proportion of area where elk pellets occurred ($\widehat{\mathrm{PAO}}_{\mathrm{t}}$), during late winter surveys in Fort Clatsop unit of Lewis and Clark NHP, 2009-2012. Also shown are total number of plots searched by year, along with the standard error for $\widehat{\mathrm{PAO}}_{\mathrm{t}}$ in each year, and the estimated per-observer mean detection probability, $\hat{\mathrm{p}}_{\mathrm{t}}$.

Year	Detected / Searched (Percentage)	$\widehat{\mathrm{PAO}}_{\mathrm{t}}$	SE($\widehat{\mathrm{PAO}}_{\mathrm{t}}$)	$\hat{\mathrm{p}}_{\mathrm{t}}$
2009	27 / 61 (44%)	0.5032	0.0705	0.4639
2010	30 / 66 (45%)	0.5239	0.0722	0.8278
2011	23 / 64 (36%)	0.447	0.0714	0.8512
2012	25 / 65 (38%)	0.4401	0.0703	0.7264

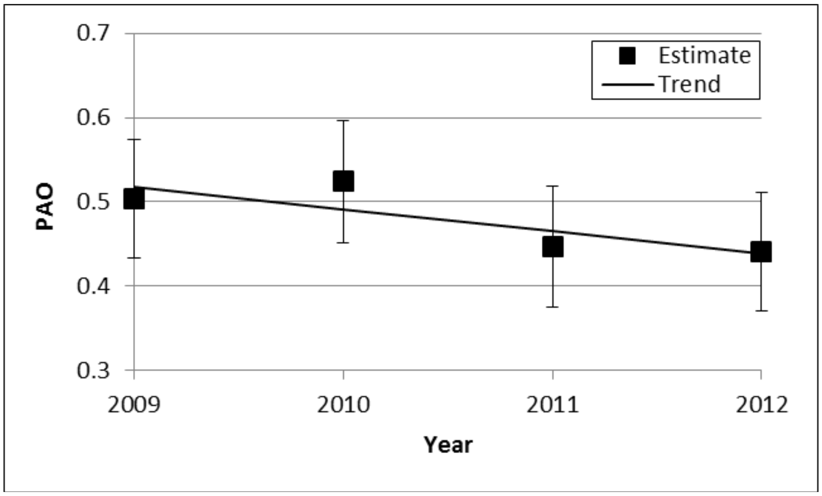

Figure 19. Estimated mean proportion of areas where elk pellets occurred ($\widehat{\mathrm{PAO}}_t$, y-axis) and regression trend line for the Fort Clatsop unit of Lewis and Clark NHP, 2009-2012. The trend line was fitted using weighted linear least squares regression. Error bars around each point are + / - 1 standard error.

Road Surveys

After initial training in October-November 2008, we completed 3-5 surveys each month from December 2008-April 2011, and every other month after April 2011 (Table 7). We only examined trends for months with road surveys each year: February, April, June, August, October, and December. We began surveying on route 2 east of the Lewis and Clark River in February 2010.

Table 7. The number of road surveys conducted each month in and around the Fort Clatsop Unit of Lewis and Clark NHP, 2008-2011. Each survey included four driving routes, all completed on the same morning.

Month	2008	2009	2010	2011	2012
January		4	4	4	
February		3	3	3	3
March		3	5	5	
April		4	4	4	4
May		4	3		
June		5	5	5	4
July		4	4		
August		3	5	4	4
September		5	4		
October	1	4	3	4	4
November	1	4	3		
December	4	4	5	5	

Mean numbers of elk groups seen per survey varied both monthly and annually but peaked in June (Figure 20). We observed a monthly average of ~2.0 elk groups per survey during June, and from ~0.8 to ~1.4 elk groups per survey in other months. All six months for which we estimated a trend had negative point estimates for the slope of annual change in the number of elk groups seen per survey (Table 8). Given the nominal rate of Bonferroni-adjusted Type I error, though, no month had a slope estimate that was statistically significantly different from zero (Table 8).

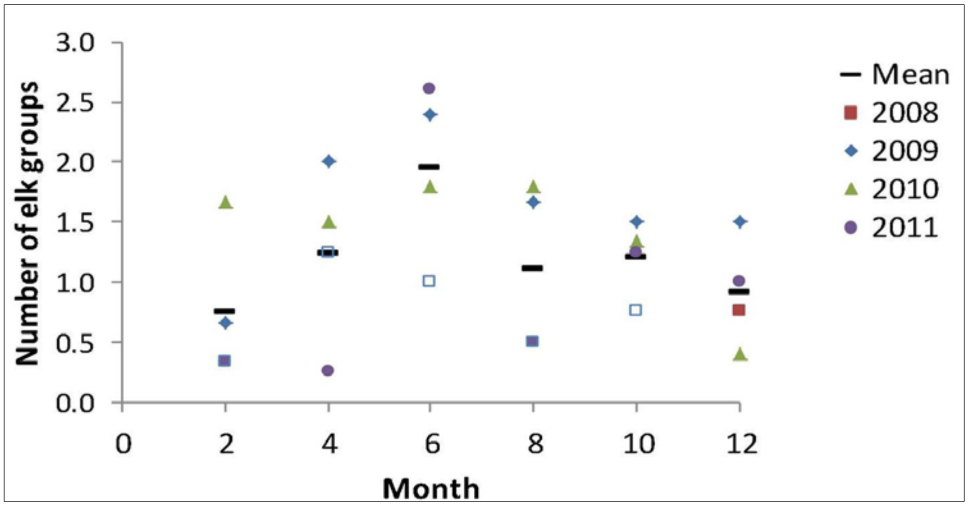

Figure 20. Average number of elk groups seen during morning roadside surveys conducted in and around the Fort Clatsop Unit, Lewis and Clark NHP, 2008-2012. Black bars indicate monthly averages, 2008-2012.

The total number of elk individuals observed per survey was relatively stable across months (Figure 21), with 22-31 elk seen per survey on average. There was no statistically significant trend of increase or decline in the total number of elk seen per survey in any month (Table 8).

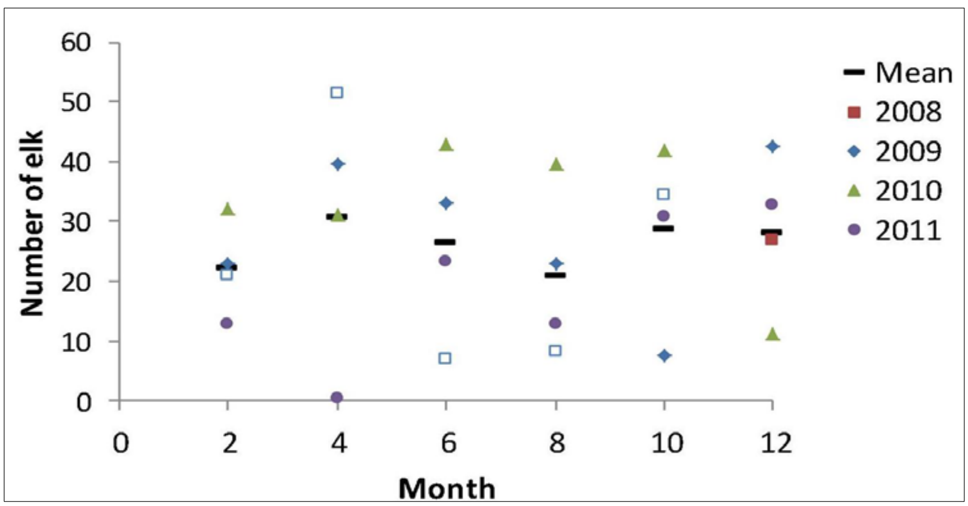

Figure 21. Average number of elk individuals observed during morning roadside surveys conducted in and around the Fort Clatsop Unit, Lewis and Clark NHP, 2008-2012. Black bars indicate monthly averages, 2008-2012.

Ratios of observed antlered (i.e., bull) to antlerless elk tended to reach the highest levels in August (Figure 22). Similarly, the observed monthly ratios of calves to antlerless elk tended to reach the lowest levels in spring, when few calves were recorded, and the highest levels in summer, at which time many cow elk had calves nearby (Figure 22). Across the four months for which trends were calculated, (Jun, Aug, Oct, Dec), and given the nominal Bonferroni-adjusted Type I error, there were no months with a significant positive or negative trend in the annual rate of change of the antlered:antlerless adult elk ratio or calf:antlerless adult elk ratio (Table 8).

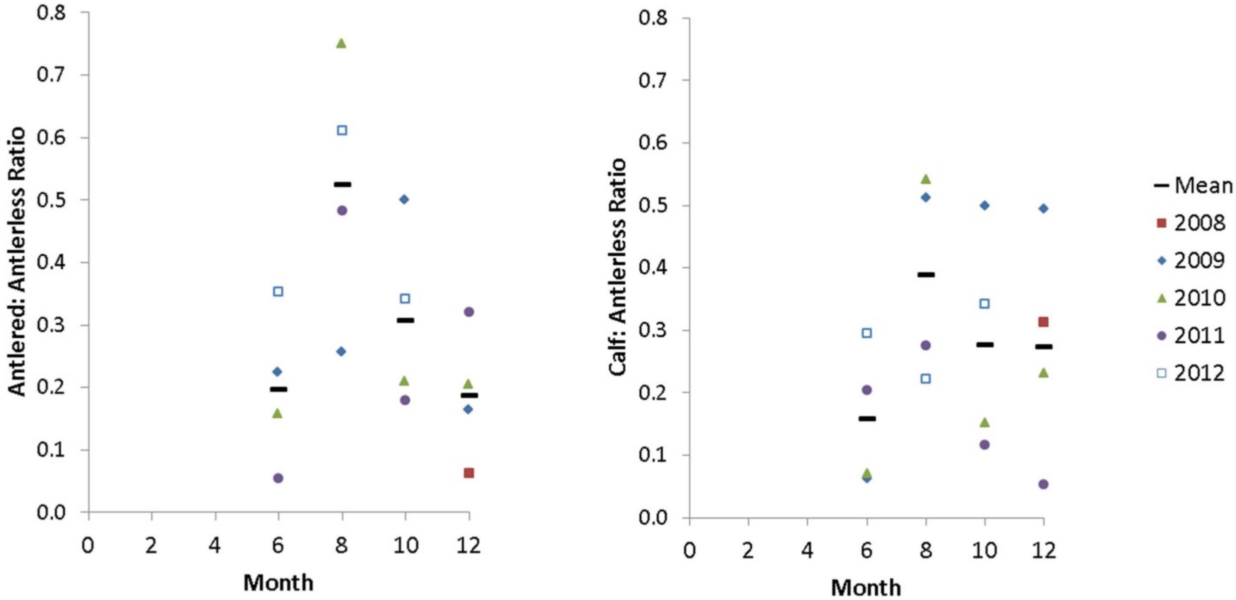

Figure 22. Monthly ratios of antlered (i.e., bulls) to antlerless adult elk (at left) and calf elk to antlerless adult elk (at right) observed on road surveys, 2008-2012. Values are only shown for months when classification is reliable (June – December). Black bars indicate monthly averages, 2008-2012.

Table 8. Slopes of the regression lines describing trends in counts and composition of elk groups observed in and around Fort Clatsop unit of Lewis and Clark NHP, 2008-2012. Slopes of the trends in monthly mean numbers of elk groups (Groups) or total elk (Total) seen per survey are from linear regressions weighted by the inverse of variance (Gerrodette 1991). Slopes in the trends in monthly ratios of antlered (i.e., bulls) to antlerless elk (B:A) and ratios of calves to antlerless elk (C:A) are reported for June to December, based on unweighted least squares regression lines. The P-value for each measure's slope reflects a 2-tailed t-test of a difference from a slope of zero. After Bonferroni adjustments, the critical P-value was 0.017 for Groups and Total, and was 0.025 for A:A and C:A.

Month	Groups	P, Groups	Total	P, Total	B:A[2]	P, B:A	C:A[2]	P, C:A
February	-0.44	0.34	-4.32	0.41				
April	-0.35[1]	0.39	32.05	0.49				
June	-0.34[1]	0.39	-10.74	0.15	0.03	0.38	0.08	0.19
August	-0.45	0.15	-5.44	0.47	0.08	0.09	-0.11	0.12
October	-0.25	0.07	14.93	0.23	-0.05	0.18	-0.05	0.36
December	-1.07	0.18	-3.04	0.74	0.08	0.05	-0.10	0.20

[1]Slope is based on unweighted regression because one value had zero variance.
[2]Slopes for composition measures are based on unweighted regression.

Elk Locations on Road Surveys

We present the observed elk locations in three 4-month periods: January – April (Figure 23), May – August (Figure 24), and September – December (Figure 25).

In all three time periods, elk were frequently observed near the northwest corner of survey route 1 (Airport), near the upstream extent of the slough west of the Astoria regional airport. Elk were also frequently recorded where routes 1 (Airport) and 2 (East Side) converge, at the intersection of the Warrenton-Astoria highway and Fort Clatsop Road. Elk were observed in several locations along the west side of the Lewis and Clark River, but were not observed east of this river.

There is a large, privately owned, upland pasture between the north-central area of the Fort Clatsop unit and the Warrenton-Astoria highway. Elk were recorded frequently in this pasture in May – August and September – December, but not in January – April.

Elk were observed in the Colewort Creek area and associated tidally influenced grasslands west of Netul landing with some regularity in the January – April and May – August periods up through 2011, but not during the September – December period.

Northeast of route 3 (Dolphin and Perkins) and southwest of route 4 (SE19th to Willow) there was a large pasture where elk were consistently observed in all time periods up through 2009. Elk had not been observed in this area during driving surveys since the January – April period of 2011. On route 4 from December 2008 to September 2010, there were 26 elk groups observed, most or all of those in the southwest area of the route. There were no elk observations on route 4 since then, though, except for one group seen in January 2011. A housing development in this area was built starting in 2008, and the pasture was subsequently fenced for cattle grazing.

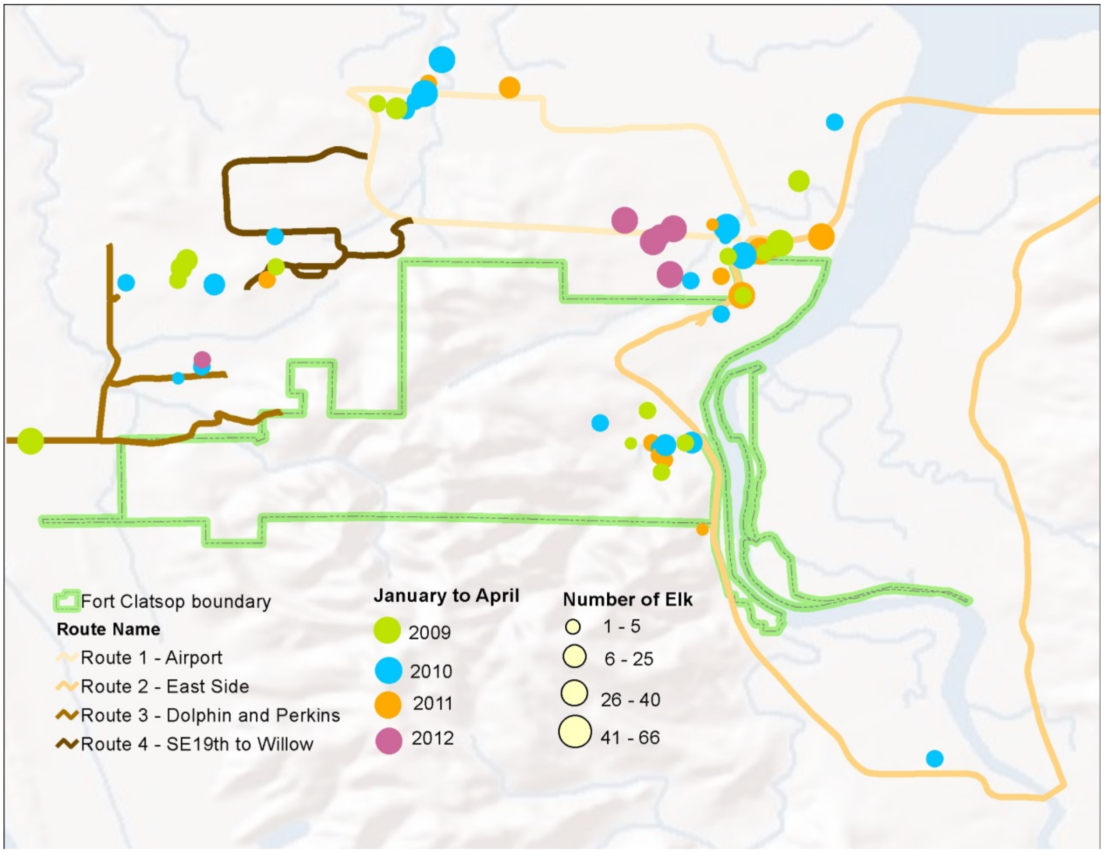

Figure 23. Locations where elk groups were seen during morning road surveys in January - April. Circle color and size indicate year of observation and size of elk group, respectively. Surveys were conducted around the Fort Clatsop unit of Lewis and Clark NHP, 2009-2012. Surveys were conducted on Route 2 east of the Lewis and Clark River after January 2011. Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture).

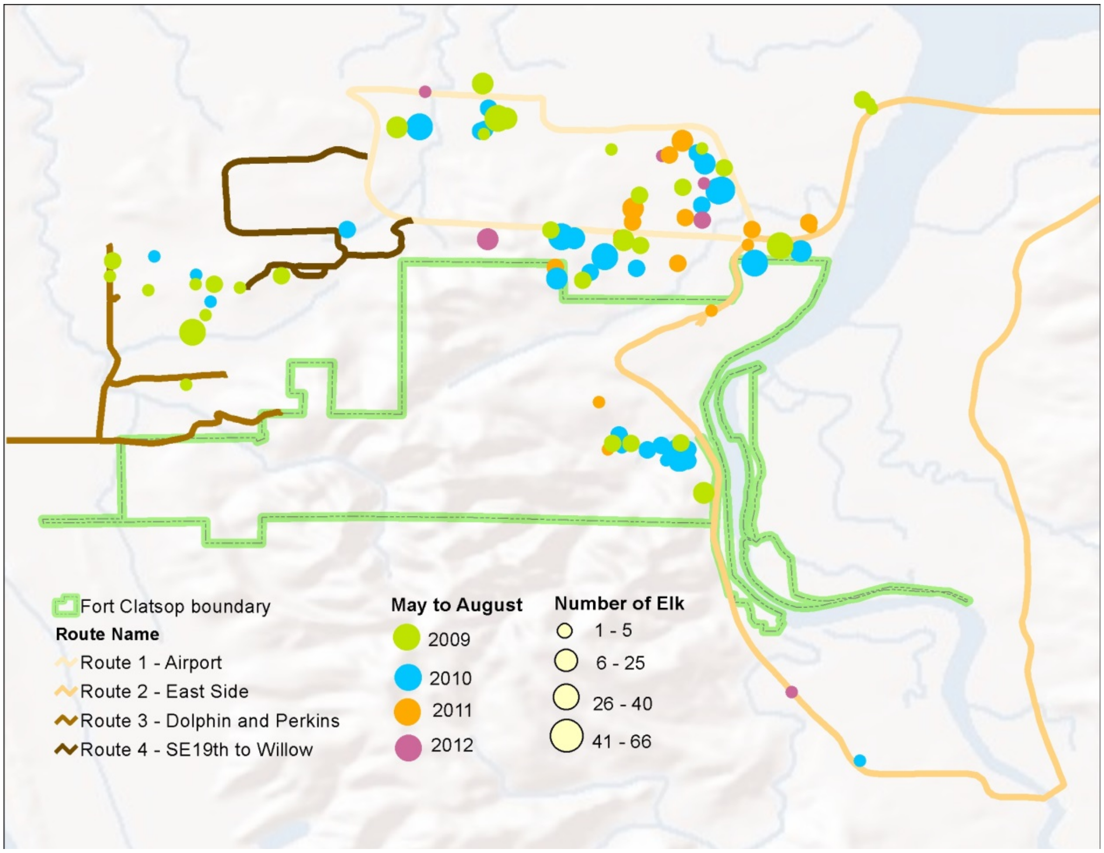

Figure 24. Locations where elk groups were seen during morning road surveys in May - August. Circle color and size indicate year of observation and size of elk group, respectively. Surveys were conducted around the Fort Clatsop unit of Lewis and Clark NHP, 2009-2012. Surveys were conducted on Route 2 east of the Lewis and Clark River after January 2011. Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture).

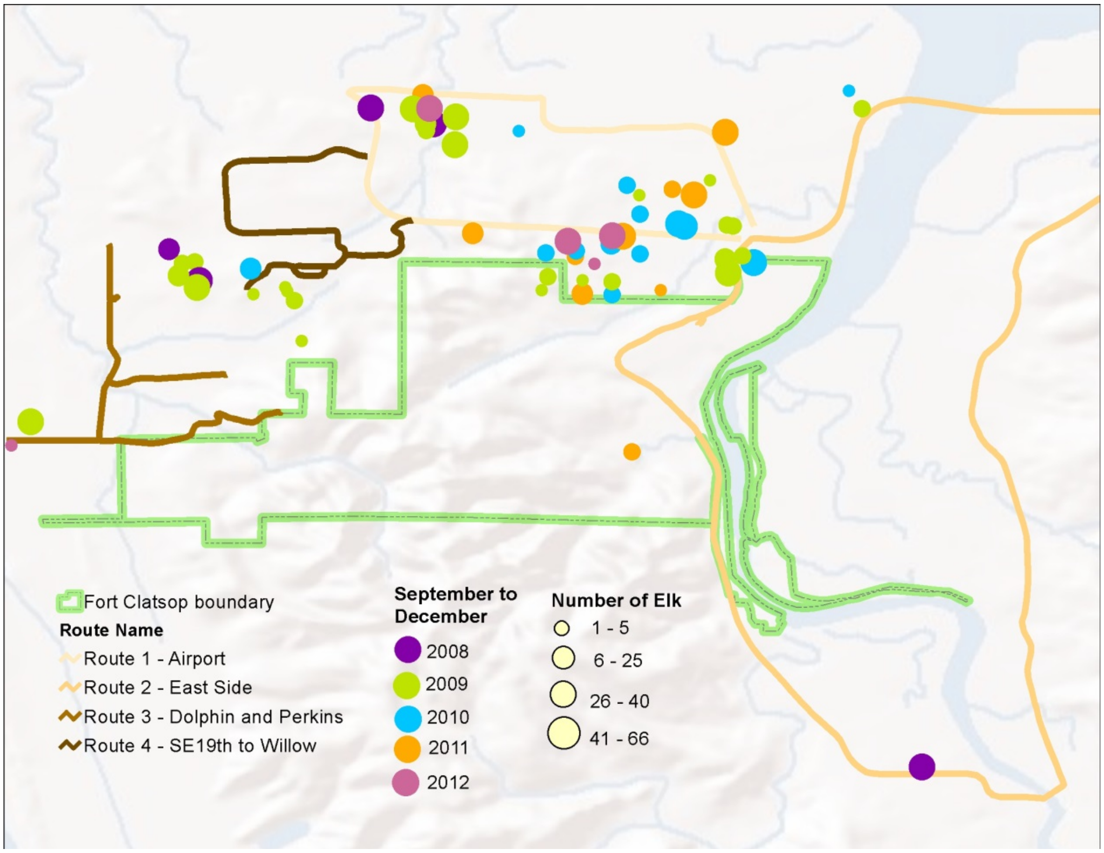

Figure 25. Locations where elk groups were seen during morning road surveys in September - December. Circle color and size indicate year of observation and size of elk group, respectively. Surveys were conducted around the Fort Clatsop unit of Lewis and Clark NHP, 2008-2012. Surveys were conducted on Route 2 east of the Lewis and Clark River after January 2011. No data are included from after September 2012. Satellite imagery is from 2011 (National Agriculture Imagery Program, US Department of Agriculture).

Discussion

Elk played an important role in sustaining the Corps of Discovery. Thus, they are an historically important natural resource at LEWI. Better understanding of elk use patterns and trends in and near the Fort Clatsop unit was sought through this monitoring program to inform park management, both in the guidance of NPS management decisions and for use in collaboration with park neighbors. Information about elk is also valuable for use in communicating to the public about the history of the park and the current conditions of the park's natural resources. The first four years of elk monitoring at Lewis and Clark NHP met the park's elk monitoring goals by successfully measuring the magnitude and spatial patterns of elk use. Pellet group surveys allowed us to interpret spatial and temporal variation in the distribution of elk use throughout the Fort Clatsop unit, and road surveys provided a record of elk sightings in and near the Fort Clatsop unit.

Park staff put in substantial effort to establish the systematic grid of elk pellet survey points across the Fort Clatsop unit in the first year of the program. The annual fall and late winter surveys still require a commitment of staff time, but the time required has become more predictable. One strength of elk monitoring at Lewis and Clark NHP is that volunteers and staff from all Lewis and Clark NHP divisions are now regular contributors to pellet and road surveys. The fact that staff twice yearly walk throughout the Fort Clatsop unit has led to synergistic benefits not discussed in this report, such as the discovery of invasive plant patches, the documentation of fungal, plant, mammal, and amphibian species, and a better appreciation of the park's geography and natural resources.

In the first four years of elk monitoring at LEWI, costs were borne largely by the park's base funding, biennial funding from the NCCN Inventory and Monitoring (I&M) Program, and support from USGS National Parks Monitoring Program. Although the initial NCCN I&M funding was sufficient to conduct these surveys every other year from 2010 to 2012, Lewis and Clark NHP staff maintained the surveys annually to prevent any discontinuity in data collection during the first 4 years of implementation. Since elk monitoring at Lewis and Clark NHP was initiated, there have been only two notable changes in the survey methods. Beginning in fall 2011, fall pellet clearing surveys were simplified so that they require less complex data collection than the spring surveys; the change reduces the required staff time in the fall. We also decreased the frequency of road surveys, so that they are now conducted in six months every year. Those changes, both approved in the final protocol (Griffin et al. 2011), did not affect any trend estimates presented in this report.

Elk Pellet Surveys

We inferred both temporal and spatial trends in winter pellet group density and temporal trends in the proportion of the Fort Clatsop unit in which elk pellets occurred during winter (PAO), based on late winter pellet group surveys. Measures of pellet group density and PAO both declined in the four years of study, but neither decline was statistically significant. In developing the protocol for this monitoring project we forecasted that the proposed sampling was sufficient to detect a 5% annual decline in pellet density or PAO after approximately 15 years of sampling (Griffin et al. 2011). If the observed trends in PAO and pellet group density continue at the present rate, however, it is likely that these declines would be statistically significant by the sixth year of monitoring (i.e., after two more years of surveys). The difference is related to the fact that the program was designed for alternate-year sampling, but pellet group surveys have been conducted annually during the first four years of the program. This higher sampling frequency has produced a greater density of annual estimates than was initially forecast. Moreover, initial estimates of declining pellet group density (about 8% per year) were greater than the 5% used in forecasting.

Preliminary indications of declining pellet densities and proportion of areas where pellet groups occurred should be interpreted with caution for two reasons. First, the lack of statistical significance highlights the fact that 4 years is a relatively small sample for the analysis of temporal trend – random variations in the first or last year's estimates may have strong stochastic effects on the estimated rate of change. Second, because the sampled area within Fort Clatsop unit is small (495 ha) relative to the seasonal range of most resident elk herds in coastal forests of the Pacific Northwest (300-1000 ha; Franklin and Lieb1979, Jenkins and Starkey 1982), changes in pellet group density may reflect changes in elk distribution within the herd range rather than population decline.

The analysis of elk pellet group detection probabilities demonstrated the importance of accounting for the factors that lead to some pellet groups going unseen during surveys (detection bias). We estimated the effects of detection bias using double-observer field and analytical methods. Accounting for the estimated detection probabilities increased the estimates of pellet density and PAO compared to what would have resulted from uncorrected raw counts. Estimated pellet group densities, $\widehat{G}_{\text{mean,t}}$, were at least twice as great as the raw (uncorrected) counts of pellet groups per subplot, $R_{\text{mean,t}}$, and PAO estimates were 14-20% greater than the raw (uncorrected) percentages of plots where pellets were detected (Table 6). Not surprisingly, we found that elk pellet groups containing fewer pellets were more difficult to find; highly decayed pellets were more difficult to find; and having two observers improved the probability of detecting pellet groups. Our correction factors accounted for those factors. We found little support for two *a posteriori* models of detection probabilities that included the effects of observer experience, but reexamination of those potential effects would be worthwhile in future analyses of pellet group detection. In a forthcoming USGS administrative report to the NPS, we will present detailed analytical methods so that the next 4-year synthesis report can repeat the entire set of trend analyses and double-observer analyses made for this report.

The systematic sample of pellet points allowed us to assess spatial associations and changes in the spatial distribution of elk pellet group density throughout the Fort Clatsop unit. We estimated the highest late-winter elk pellet group densities were in the southeast part of the unit, near Colewort Creek (Figure 17). This is an area of the park where there is relatively little human use of forested habitats, and the riparian vegetation and freshwater wetland there provide important forage used seasonally by elk. Elk groups were often observed in the area on road surveys from January to August; this period coincides with seasons when wetland plants such as skunk cabbage (*Lysichiton americanus*), slough sedge (*Carex obnuta*), and salmonberry (*Rubus spectabilis*) are commonly sought by elk (Jenkins and Starkey 1991). Although the pellet group survey methods in this monitoring project provide an index of winter use only, the consistent detection of elk pellets in this area during fall clearing sessions (Appendix A of this report, Cole et al. 2012), along with elk sightings in this area during roadside surveys from January to August (Figures 24, 25), suggest that the area near Colewort Creek provides valuable habitat used by elk throughout much of the year.

We chose systematic sampling for the pellet group surveys so that it would be possible to examine changes in the distribution of elk use over time, relative to natural processes such as forest succession or in response to management actions implemented by the NPS. For example, we examined temporal patterns in pellet-group density in areas disturbed by the December 2007 wind storm. Immediately after the storm, there was concern that the ‘jackstraw’ of fallen trees would prevent elk from accessing and using sites with high blowdown severity. On the other hand, since fall 2008 we have witnessed understory plant growth in these forest stands resulting from secondary succession, and tree stems are beginning to decay. We hypothesize that, in the future, increased forage production associated with forest openings and the decay of windthrown trees may improve local habitat conditions within wind-disturbed areas and attract elk. Because we have no pellet densities from before the storms, it was not possible to assess the effects of the windstorms on local elk use patterns before and after the storm. Our post hoc analysis of pellet group density trends in these recently disturbed forests relied on a small sample size (n=13), but the results at those points were not qualitatively or statistically different from other points in the sample. At points with high blowdown severity we observed elk use in the winter of 2009, and then a decline in pellet group density over time, similar to results at all other points. Continued elk pellet group monitoring at all of the accessible points on the systematic pellet survey grid should allow for an improved understanding of the effects of windthrow and forest succession on elk over the long term. Other similar applications might include looking at changes in pellet group frequencies or occurrence patterns related to forest succession following planned forest restoration activities, such as variable-density thinning (NPS 2011).

As an example related to park management, we also assessed whether or not the development of new hiking trails may have influenced local patterns of pellet group density in the Fort Clatsop unit during winter. Two trails were developed recently: the South Slough trail was built in the lower Colewort Creek watershed during the summer of 2010 and its lower spur in summer of 2011; and the Kwis Kwis trail at the Fort Clatsop unit’s northern end was developed during the summer of 2011. We recorded a small, potential shift in the spatial distribution of standardized pellet group density in the southeast region of the unit in the vicinity of the South Slough trail, but it is not clear whether or not this local change in distribution is associated with construction of the South Slough trail in summer 2010. The Kwis Kwis trail at the Fort Clatsop unit’s northern end does not seem to be associated with any local reduction in pellet group density; at one survey point near the Kwis Kwis trail standardized pellet group density actually increased significantly from 2009-2012. Although trails developed since 2010 probably facilitated visitor access in both of these locales, any negative effect of that access is not immediately apparent in results from late winter pellet group density estimates. The effect of visitor use on elk may be greater in spring, summer, and fall as visitor trail use is relatively low in winter, with only ~2.6 groups of hikers per trail per day using the South Slough trail in January 2012 (Lewis and Clark NHP resource staff, based on remote camera data).

Road Surveys

Results from road surveys were a reflection of the elk viewing opportunities for park visitors driving in the area. Because the road surveys do not include methods to account for elk group visibility, and because the routes are a non-random sample of elk habitats, changes in the number of elk groups seen in any particular area should not be interpreted as direct evidence of changes in the underlying number of elk in the area. Despite this caveat, the road survey results are an accurate measure of what park visitors might expect to see in the vicinity of the Fort Clatsop unit.

Road surveys documented consistent seasonal patterns in elk group detections on roads in and near the Fort Clatsop unit. Survey crews typically recorded the greatest number of elk groups during June, although these groups tended to be smallest during June, which is consistent with calving and post-calving behavior (Geist 2002). The ratio of bulls and calves seen on road surveys increased during late summer, reflecting the increased aggregation of females with young during late summer and the mixing of males and females prior to breeding (Franklin and Lieb 1979, Geist 2002). Although there appeared to be a small decline in the number of elk groups and total number of elk seen per survey between 2008-2012, those apparent trends were not statistically significant. As with the pellet group surveys, additional years of continued monitoring may reveal a statistically significant change in the number of elk groups seen per survey or in the total number of elk seen per survey.

Within the Fort Clatsop unit, elk were most commonly seen in the vicinity of Colewort Creek slough and nearby old upland pastures. Elk were frequently observed there during road surveys in the January-April and May-August periods, but were recorded there only once in the September-December period. In 2012 and 2013, the park has been actively restoring tidal conditions and has planted woody and herbaceous native plants extensively in the hopes of improving salmon habitat. As these new plants grow, they may shield elk from observers on road surveys in the future. As a consequence, trends in pellet densities recorded in this area may provide a better long-term index of elk use than observations.

Elk were frequently seen on road surveys in the pasture to the north of the Fort Clatsop unit in May-August and September-December, but were not recorded there as often in January-April. The majority of park visitors drive past this field just before they turn from the Warrenton-Astoria Highway south onto Fort Clatsop Road.

Many elk groups were also observed in other locations north of the Fort Clatsop unit, near the intersection of the Warrenton-Astoria highway and Fort Clatsop Road, south of the airport, and to the west of the airport in areas drained by Adair Slough and Vera Creek. Since road surveys began in late 2008, residential development and commercial development have increased on lands outside the park. In 2008, construction began on two major ‘box’ stores and adjacent parking lots in the Highway 101/ Ensign Lane area, but those areas were not part of our surveys. The reduced frequency of elk sightings in the upper part of the Adair slough watershed from 2009-2012, however, may have been related to housing development between 2008-2012. Roads and some houses were present on Willow and Salal roads in 2008. More houses were built there since then, and the pasture to the west of those roads was fenced. Since 2010, road surveys have recorded only one elk group in the vicinity of that housing development and pasture.

Conclusions

The first four years of monitoring suggest an incipient declining trend in the use of the Fort Clatsop unit and adjacent areas by elk from 2008-2012, but additional years of monitoring are needed to confirm these trends. Annual monitoring provides a baseline for future comparisons in and around the Fort Clatsop Unit of LEWI.

We presented examples of how the monitoring data may be used to examine effects of forest succession and park management activities on elk distribution and use patterns in LEWI. After only four years of data collection, data were too sparse to reliably discern statistically significant trends related to forest succession or trail construction. Continued monitoring will enhance the ability of this project to provide meaningful interpretations of elk responses to local succession and management practices.

Habitat loss associated with the expansion of housing and commercial developments around the Fort Clatsop unit may influence both the sightability of elk around the park, and relative use patterns of elk within the Fort Clatsop unit. Additional research on elk movements in and around the park would increase understanding of the potential effects on elk of land-use changes such as those quantified by the NCCN Landscape Dynamics monitoring project.

We did not identify deficiencies or recommend any significant modifications to the established protocol. Although we recognized limitations in inferences that can be made from pellet group and roadside surveys regarding absolute population trends, the protocols are inexpensive to implement and meet the objectives of discerning changes in elk relative use in and around the Fort Clatsop unit. We identified a potentially useful refinement of models for estimating detection biases based on observer experience, although we found little statistical support for such models at this time. We also suggest that with greater data available in the future, it may be useful to examine additional hypotheses that would explain patterns of pellet occurrence or density in relation to vegetation classes or management activities.

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Appendix A. Annual Results from FY 2011 and FY 2012.

The methods used in FY 2011 and FY 2012 are discussed at length in the preceding 4-year synthesis report. In this appendix, we present the tabular data that would be presented in a biennial report, if the 4-year report were not being published at the same time.

Field Crew

Carla Cole was the Project Lead in this study during FY 2011 and FY 2012. Field crew that took part in fall and late winter pellet sampling sessions are listed in Tables A.1 and A.2. Field crew members that took part in road surveys are listed in Tables A.3 and A.4.

Table A.1. Observers that participated in pellet surveys in October-November 2010 and February-March 2011, Lewis and Clark NHP. Lewis and Clark NHP staff are identified by the division with which they are affiliated.

Affiliation	Names
Resources Division	Carla Cole, Nancy Eid, Jason Smith
Maintenance Division	Doug Graham
Administrative Division	Blake Gertulla
Other Observers	Paul Griffin (USGS), John Wickersham (North Coast Land Conservancy)

Table A.2. Observers that participated in pellet surveys in October-November 2011 and March 2012, Lewis and Clark NHP. Lewis and Clark NHP staff are identified by the division with which they are affiliated.

Affiliation	Names
Resources Division	Jenny Bell, Chris Clatterbuck, Carla Cole, Dustin Henkin, Craig Feigenbaum
Maintenance Division	Andy Rasmussen
Interpretive Division	Will George, Patricia Ciminello, Susan Rhoads
Administrative Division	Blake Gertulla
Other Observers	Paul Griffin (USGS)
Community Volunteers	Delpha Krabbe, Ruthie King, Aaron Schlosser

Table A.3. Observers that participated in road surveys from October 2010 to September 2011, Lewis and Clark NHP. Lewis and Clark NHP staff are identified by the division with which they are affiliated.

Affiliation	Names
Resources Division	Jenny Bell, Zach Bolitho, Chris Clatterbuck, Carla Cole, Nancy Eid, Dustin Henkin, Lynne Johnson
Interpretive Division	Susan Rhoads
Community Volunteers	Rachel Stokeld, Russ Greenburg, Jerry Ostermiller

Table A.4. Observers that participated in road surveys from October 2011 to September 2012, Lewis and Clark NHP. Lewis and Clark NHP staff are identified by the division with which they are affiliated.

Affiliation	Names
Resources Division	Jenny Bell, Chris Clatterbuck, Carla Cole, Craig Feigenbaum, Dustin Henkin
Administrative Division	Blake Gerttula

Pellet Survey

FY 2011

Pellet surveys took place in the fall from October 25 to November 5, 2010. Late winter pellet surveys took place from February 28 to March 8, 2011. We conducted pellet surveys at 63 points in the late winter. The uncorrected (raw) average number of pellet groups per subplot counted in late winter at each point, *i*, in year *t*, is called $R_{i,t}$. By applying correction factors that accounted for detection probability, we found the estimated pellet group density at each point, $\hat{G}_{i,t}$. Units for both measures are pellet groups per subplot. Table A.5 presents values of $R_{i,t}$ and $\hat{G}_{i,t}$ for each point surveyed in late winter FY2011.

Table A.5. Summary of results from each point surveyed for pellets in late winter, 2011. The date for each point is the date when it was surveyed. $R_{i,2011}$ is the average number of pellet groups per subplot observed in late winter 2011 at each pellet survey point. $\hat{G}_{i,2011}$ is the estimated number of pellet groups present at the point, after accounting for detection bias. Var($\hat{G}_{i,2011}$) is the estimated variance in the $\hat{G}_{i,2011}$ value for the point.

Point	Date	$R_{i,2012}$	$\hat{G}_{i,2012}$	Var($\hat{G}_{i,2012}$)	Point	Date	$R_{i,2012}$	$\hat{G}_{i,2012}$	Var($\hat{G}_{i,2012}$)
0	2/28/2011	1.75	2.673	0.078	46	3/1/2011	0.00	0.000	0.000
1	2/28/2011	0.00	0.000	0.000	47	3/1/2011	0.00	0.000	0.000
2	2/28/2011	0.75	4.096	0.758	48	3/1/2011	1.25	6.214	2.274
6	2/28/2011	0.00	0.000	0.000	49	3/1/2011	0.00	0.000	0.000
7	2/28/2011	0.50	1.117	0.019	51	3/7/2011	0.75	3.090	0.433
8	3/2/2011	0.00	0.000	0.000	52	3/3/2011	0.50	0.717	0.001
9	3/2/2011	0.00	0.000	0.000	53	3/3/2011	0.00	0.000	0.000
10	3/2/2011	0.00	0.000	0.000	54	3/3/2011	0.25	0.485	0.007
11	3/2/2011	0.00	0.000	0.000	55	3/3/2011	0.00	0.000	0.000
12	3/11/2011	0.00	0.000	0.000	56	3/8/2011	0.33	0.613	0.002
14	3/3/2011	0.00	0.000	0.000	57	3/8/2011	0.00	0.000	0.000
15	3/3/2011	0.50	0.893	0.041	58	3/11/2011	0.50	2.013	0.374
17	3/4/2011	0.00	0.000	0.000	59	3/4/2011	0.00	0.000	0.000
18	3/4/2011	0.00	0.000	0.000	60	3/11/2011	0.00	0.000	0.000
19	3/2/2011	0.00	0.000	0.000	61	2/28/2011	0.25	0.271	0.000
21	3/3/2011	0.00	0.000	0.000	62	2/28/2011	0.00	0.000	0.000
23	3/3/2011	0.00	0.000	0.000	64	2/28/2011	1.75	4.302	2.378
25	3/4/2011	0.00	0.000	0.000	65	3/7/2011	0.00	0.000	0.000
26	3/2/2011	0.00	0.000	0.000	66	3/3/2011	0.00	0.000	0.000
29	3/4/2011	0.00	0.000	0.000	67	3/3/2011	0.00	0.000	0.000
30	3/4/2011	0.00	0.000	0.000	68	3/3/2011	0.00	0.000	0.000
31	3/4/2011	0.50	0.535	0.000	70	3/4/2011	0.25	0.275	0.000
33	3/2/2011	0.00	0.000	0.000	71	3/4/2011	0.00	0.000	0.000
34	3/3/2011	1.00	1.048	0.000	72	3/4/2011	0.50	0.572	0.000
35	3/4/2011	0.00	0.000	0.000	73	3/4/2011	0.00	0.000	0.000
37	3/4/2011	1.75	2.318	0.003	74	3/4/2011	1.75	2.060	0.001
39	3/4/2011	0.00	0.000	0.000	75	2/28/2011	0.25	1.858	0.551
40	3/3/2011	0.00	0.000	0.000	76	2/28/2011	0.00	0.000	0.000
42	3/4/2011	0.00	0.000	0.000	77	2/28/2011	0.50	0.621	0.001
43	3/4/2011	0.75	1.074	0.013	78	3/4/2011	0.25	0.274	0.000
44	3/4/2011	0.00	0.000	0.000	79	3/4/2011	0.00	0.000	0.000
45	3/1/2011	0.25	0.546	0.018	80	3/7/2011	0.00	0.000	0.000

Points 3, 4, 5, 13, 16, 20, 22, 24, 27, 28, 32, 36, 38, 41, 50, 63, 68, and 69, were not sampled because they were underwater, unsafe to access because of steep terrain, or on private property. See figure A.1.

Of the 64 points sampled in the fall, 28 had one or more elk pellet groups detected in any of the subplots (Figure A.1). Of the 64 points sampled in the late winter, 23 had one or more elk pellet groups detected in any of the subplots (Figure A.1). Of these two sampling sessions, only the late winter session is associated with a known pellet deposition time period.

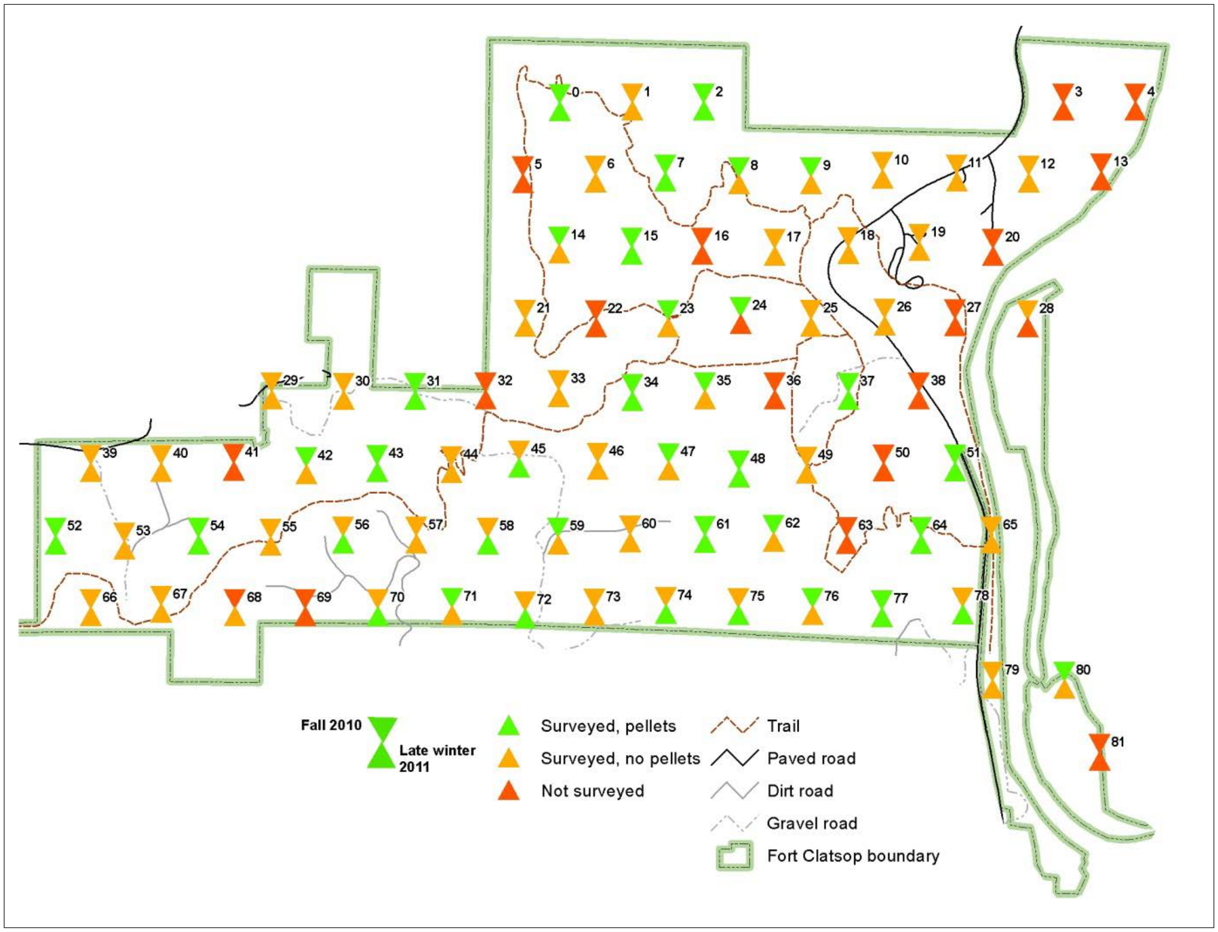

Figure A.1. Map of elk pellet detections in subplots of surveyed points for the Fort Clatsop unit of Lewis and Clark NHP, fall 2011 and late winter 2012. At each point the upper triangle is for the fall 2011 clearing session, and the lower triangle is for the late winter 2012 survey session. Points at which elk pellets were detected in any subplot are shown as green triangles. Surveyed points at which no elk pellets were detected are shown as orange triangles. Points that were not sampled are shown as red triangles.

FY 2012

Pellet surveys took place in the fall from October 24 to November 1, 2011. Late winter pellet surveys took place from March 5 to March 16, 2012. We conducted pellet surveys at 65 points in the late winter, where pellets had been cleared in the fall. Table A.6 presents values of $R_{i,t}$ and $\hat{G}_{i,t}$ for each point sampled in late winter of FY2012.

Table A.6. Summary of results from each point surveyed for pellets in late winter, 2012. The date for each point is the date when it was surveyed. $R_{i,2012}$ is the average number of pellet groups per subplot observed in late winter 2012 at each pellet survey point. $\hat{G}_{i,2012}$ is the estimated number of pellet groups present at the point, after accounting for detection bias. Var($\hat{G}_{i,2012}$) is the estimated variance in the $\hat{G}_{i,2012}$ value for the point.

Point	Date	$R_{i,2012}$	$\hat{G}_{i,2012}$	Var($\hat{G}_{i,2012}$)	Point	Date	$R_{i,2012}$	$\hat{G}_{i,2012}$	Var($\hat{G}_{i,2012}$)
0	3/5/2012	0.25	0.776	0.022	45	3/6/2012	0.00	0.000	0.000
1	3/5/2012	0.00	0.000	0.000	46	3/16/2012	0.00	0.000	0.000
2	3/5/2012	0.50	2.754	0.844	47	3/5/2012	0.00	0.000	0.000
6	3/5/2012	0.00	0.000	0.000	48	3/5/2012	0.75	1.521	0.235
7	3/5/2012	1.25	2.341	0.035	49	3/5/2012	0.00	0.000	0.000
8	3/6/2012	0.00	0.000	0.000	51	3/14/2012	1.00	2.600	0.376
9	3/6/2012	0.00	0.000	0.000	52	3/5/2012	0.25	0.372	0.001
10	3/8/2012	0.00	0.000	0.000	53	3/5/2012	0.00	0.000	0.000
11	3/5/2012	0.00	0.000	0.000	54	3/5/2012	0.25	0.991	0.237
12	3/6/2012	0.25	0.461	0.009	55	3/14/2012	0.00	0.000	0.000
14	3/8/2012	0.00	0.000	0.000	56	3/14/2012	0.00	0.000	0.000
15	3/8/2012	0.00	0.000	0.000	57	3/7/2012	0.25	0.461	0.002
17	3/16/2012	0.00	0.000	0.000	58	3/7/2012	1.75	2.656	0.011
18	3/8/2012	0.00	0.000	0.000	59	3/8/2012	0.00	0.000	0.000
19	3/14/2012	0.00	0.000	0.000	60	3/8/2012	0.25	0.285	0.000
21	3/8/2012	0.00	0.000	0.000	61	3/8/2012	0.50	0.594	0.000
23	3/6/2012	0.00	0.000	0.000	62	3/8/2012	0.50	1.573	0.140
24	3/6/2012	0.50	0.604	0.000	64	3/9/2012	1.25	2.182	0.237
25	3/9/2012	0.00	0.000	0.000	65	3/9/2012	0.00	0.000	0.000
26	3/14/2012	0.00	0.000	0.000	66	3/5/2012	0.25	0.993	0.057
28	3/8/2012	0.00	0.000	0.000	67	3/14/2012	0.00	0.000	0.000
29	3/9/2012	0.00	0.000	0.000	70	3/7/2012	0.00	0.000	0.000
30	3/9/2012	0.00	0.000	0.000	71	3/7/2012	0.50	2.072	0.385
31	3/9/2012	0.00	0.000	0.000	72	3/7/2012	0.00	0.000	0.000
33	3/16/2012	0.00	0.000	0.000	73	3/16/2012	0.25	0.650	0.068
34	3/16/2012	0.25	1.743	0.376	74	3/16/2012	0.75	1.081	0.005
35	3/5/2012	0.50	1.901	0.095	75	3/9/2012	0.00	0.000	0.000
37	3/5/2012	3.25	3.918	0.010	76	3/9/2012	0.00	0.000	0.000
39	3/5/2012	0.00	0.000	0.000	77	3/9/2012	0.75	3.835	3.034
40	3/5/2012	0.00	0.000	0.000	78	3/7/2012	0.25	0.355	0.002
42	3/9/2012	0.00	0.000	0.000	79	3/9/2012	0.00	0.000	0.000
43	3/9/2012	0.00	0.000	0.000	80	3/8/2012	0.50	0.920	0.011
44	3/14/2012	0.00	0.000	0.000					

Points 3, 4, 5, 13, 16, 20, 22, 27, 32, 36, 38, 41, 50, 63, 68, and 69 were not sampled because they were underwater, unsafe to access because of steep terrain, or on private property. See figure A.2.

Of the 66 points sampled in the fall, 28 had one or more elk pellet groups detected in any of the subplots (Figure A.2). Of the 65 points sampled in the late winter, 25 had one or more elk pellet groups detected in any of the subplots (Figure A.2). Of these two sampling sessions, only the late winter session is associated with a known pellet deposition time period.

Figure A.2. Map of elk pellet detections in subplots of surveyed points for the Fort Clatsop unit of Lewis and Clark NHP, fall 2011 and late winter 2012. At each point the upper triangle is for the fall 2011 clearing session, and the lower triangle is for the late winter 2012 survey session. Points at which elk pellets were detected in any subplot are shown as green triangles. Surveyed points at which no elk pellets were detected are shown as orange triangles. Points that were not sampled are shown as red triangles.

Road Surveys

FY 2011

We conducted three road surveys in October 2010, November 2012, and February 2011; four surveys per month in January 2011, April 2011, and August 2011; and five surveys per month in December 2010, March 2011, and June 2011. All four routes (see Figure 6 of main report) had the same number of surveys, because all four routes were surveyed on each morning of survey. In Table A.7 we present the mean number of elk groups seen per survey, for each survey route, and associated standard errors (SE). In Table A.8 we present the mean total number of elk groups seen per survey, and associated SE. In Table A.9 we present observed values for the antlered to antlerless adult elk ratios. In Table A.10 we present observed values for the calf to antlerless adult elk ratios.

Table A.7. Mean number of elk groups seen per morning road survey, by route and across all four routes, Lewis and Clark NHP, October 2010 to September 2011. Standard errors are in parentheses.

Date	Route 1	Route 2	Route 3	Route 4	All Routes
October 2010	1.25 (0.25)	0.00	0.00	0.00	1.33 (0.33)
November 2010	0.67 (0.33)	0.00	0.00	0.00	0.67 (0.33)
December 2010	0.20 (0.20)	0.20 (0.20)	0.00	0.00	0.40 (0.24)
January 2011	0.25 (0.25)	0.75 (0.25)	0.00	0.25 (0.25)	1.25 (0.48)
February 2011	0.33 (0.33)	0.00	0.00	0.00	0.33 (0.33)
March 2011	0.2 (0.2)	1.0 (0.32)	0.00	0.00	1.20 (0.37)
April 2011	0.00	0.25 (0.25)	0.00	0.00	0.25 (0.25)
June 2011	1.4 (0.4)	1.2 (0.58)	0.00	0.00	2.60 (0.68)
August 2011	0.5 (0.5)	0.00	0.00	0.00	0.50 (0.50)

Table A.8. Mean total number of elk individuals seen per morning road survey, by route and across all four routes, Lewis and Clark NHP, October 2010 to September 2011. Standard errors are in parentheses.

Date	Route 1	Route 2	Route 3	Route 4	All Routes
October 2010	37.8 (8.3)	0.00	0.00	0.00	42.0 (10.0)
November 2010	13.3 (6.7)	0.00	0.00	0.00	13.3 (6.7)
December 2010	2.6 (2.6)	8.6 (8.6)	0.00	0.00	11.2 (8.3)
January 2011	0.25 (0.25)	17.5 (10.4)	0.00	5.8 (5.8)	23.5 (9.4)
February 2011	12.7 (12.7)	0.00	0.00	0.00	12.7 (12.7)
March 2011	1.6 (1.6)	18.6 (7.4)	0.00	0.00	20.2 (7.3
April 2011	0.00	0.5 (0.5)	0.00	0.00	0.5 (0.5)
June 2011	19.8 (4.8)	3.6 (1.8)	0.00	0.00	23.4 (4.8)
August 2011	12.8 (12.8)	0.00	0.00	0.00	12.8 (12.8)

Table A.9. Ratios of Antlered to Antlerless adult elk seen on all four survey routes, Lewis and Clark NHP, October 2010 to September 2011. The overall ratio for the month is the total number of antlered elk seen during the month divided by the total number of antlerless adult elk seen during the month. In cases where four surveys were conducted in a month, the median value was the arithmetic mean of the two central values.

Date	Ratio	Median	Low	High
October 2010	0.21	0.22	0.12	0.29
November 2010	*	*	*	*
December 2010	0.21	0.23	0.11	0.23
January 2011	0.44	0.28	0.28	0.28
February 2011	0.37	0.37	0.37	0.37
March 2011	0.83	0.17	0.17	0.17
April 2011	0.00	0.00	0.00	0.00
June 2011	0.05	0.00	0.00	0.20
August 2011	0.48	0.48	0.48	0.48

*Ratios cannot be computed for November 2010 because no cows were recorded.

Table A.10. Ratios of Calf to Antlerless adult elk seen on all four survey routes, Lewis and Clark NHP, October 2010 to September 2011. The overall ratio for the month is the total number of antlered elk seen during the month divided by the total number of antlerless adult elk seen during the month. In cases where four surveys were conducted in a month, the median value was the arithmetic mean of the two central values.

Date	Ratio	Median	Low	High
October 2010	0.15	0.16	0.059	0.21
November 2010	*	*	*	*
December 2010	0.23	0.20	0.2	0.33
January 2011	0.16	0.16	0.16	0.16
February 2011	0.63	0.63	0.63	0.63
March 2011	0.00	0.00	0.00	0.00
April 2011	0.00	0.00	0.00	0.00
June 2011	0.20	0.19	0.00	0.35
August 2011	0.28	0.28	0.28	0.28

*Ratios cannot be computed for November 2010 because no cows were recorded.

FY 2012

We conducted three road surveys in February 2012; four surveys per month in October 2011, April 2012, June 2012, and August 2012; and five surveys per month in December 2011. All four routes (see Figure 6 of main report) had the same number of surveys, because all four routes were surveyed on each morning of survey. In Table A.11 we present the mean number of elk groups seen per survey, for each survey route, and associated standard errors (SE). In Table A.12 we present the mean total number of elk groups seen per survey, and associated SE. In Table A.13 we present observed values for the antlered to antlerless adult elk ratios. In Table A.14 we present observed values for the calf to antlerless adult elk ratios.

Table A.11. Mean number of elk groups seen per morning road survey, by route and across all four routes, Lewis and Clark NHP, October 2011 to September 2012. Standard errors are in parentheses.

Date	Route 1	Route 2	Route 3	Route 4	All Routes
October 2011	1.25 (0.48)	0	0	0	1.25 (0.48)
December 2011	0.8 (0.37)	0.2 (0.2)	0	0	1.00 (0.45)
February 2012	0.33 (0.33)	0	0	0	0.33 (0.33)
April 2012	1.0 (0)	0	0.25 (0.25)	0	1.25 (0.25)
June 2012	0.75 (0.25)	0.25 (0.25)	0	0	1.00 (0.00)
August 2012	0.25 (0.25)	0.25 (0.25)	0	0	0.5 (0.29)

Table A.12. Mean total number of elk individuals seen per morning road survey, by route and across all four routes, Lewis and Clark NHP, October 2011 to September 2012. Standard errors are in parentheses.

Date	Route 1	Route 2	Route 3	Route 4	All Routes
October 2011	30.75 (18.4)	0	0	0	30.8 (18.4)
December 2011	29.8 (12.7)	2.8 (2.8)	0	0	32.6 (14.2)
February 2012	21 (21)	0	0	0	21.0 (21.0)
April 2012	49.0 (3.7)	0	2.5 (2.5)	0	51.5 (2.3)
June 2012	6.5 (4.6)	0.5 (0.5)	0	0	7.0 (4.4)
August 2012	8.0 (7.0)	0.25 (0.25)	0	0	8.3 (6.9)

Table A.13. Ratios of Antlered to Antlerless adult elk seen on all four survey routes, Lewis and Clark NHP, October 2011 to September 2012. The overall ratio for the month is the total number of antlered elk seen during the month divided by the total number of antlerless adult elk seen during the month. In cases where four surveys were conducted in a month, the median value was the arithmetic mean of the two central values.

Date	Ratio	Median	Low	High
October 2011	0.18	0.24	0.032	0.40
December 2011	0.32	0.22	0.21	0.22
February 2012	0.29	0.29	0.29	0.29
April 2012	0.06	0.06	0	0.12
June 2012	0.35	0	0	0.071
August 2012	0.61	0.53	0.5	0.56

Table A.14. Ratios of Calf to Antlerless adult elk seen on all four survey routes, Lewis and Clark NHP, October 2011 to September 2012. The overall ratio for the month is the total number of antlered elk seen during the month divided by the total number of antlerless adult elk seen during the month. In cases where four surveys were conducted in a month, the median value was the arithmetic mean of the two central values.

Date	Ratio	Median	Low	High
October 2011	0.12	0.10	0	0.14
December 2011	0.05	0.07	0	0.15
February 2012	0	0	0	0
April 2012	0.11	0.12	0	0.24
June 2012	0.29	0	0	0.36
August 2012	0.22	0.13	0	0.25

Appendix B. Incidental Observations of Elk Pellet Groups.

In addition to the quantitative analysis of pellet group density and presence at the established plots, we also mapped incidental observations of pellet groups observed by the teams travelling between sampling points. We did not intend incidental observations to be used directly to measure trend, but rather intended them to be a supplemental, approximate spatial representation of where elk pellets were seen between surveyed points. We used output of the database query **qs_Pellets_on_walk_lines**, which we imported to the geospatial database, to create maps of line segments associated with the Walking Time Data Sheets. These line segments represented the approximate paths taken by observers to reach survey points. Individual lines were defined by one "From Point" and one "To Point," and were a single row of data in the database table **tbl_Walking_Surveys**. The actual paths taken between points were almost invariably more tortuous than the simple, straight-line segments connecting the endpoints, but we mapped the points as a heuristic tool. We associated with information about whether elk pellets were seen *en route*, or not. We created maps (Figures B.1, B.2) of the line segments approximately traveled, color coded according to whether elk pellets were detected *en route*, or not.

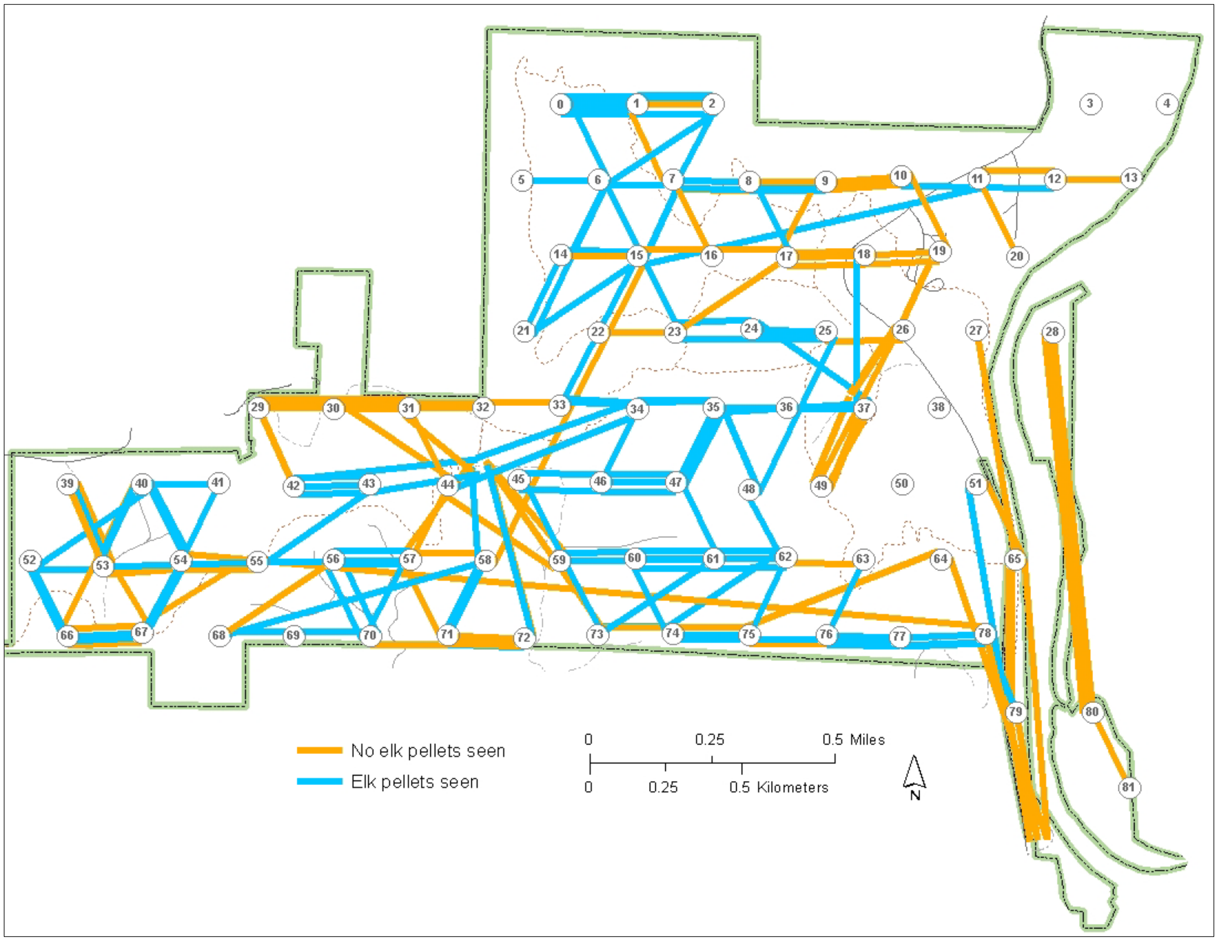

Figure B.1. Map of estimated distribution of elk pellets observed while en route between survey points, Fort Clatsop unit of Lewis and Clark NHP, fall 2008-2011. Each line segment is colored to indicate whether elk pellets were noted (blue) or were not noted (orange). Years of data are presented adjacently.

Although these mapped detections were not quantified, they suggest that there may be differences in the distributions of elk fecal pellets seen in fall (Figure B.1), compared to those seen in late winter (Figure B.2). At the far west and in the north-central portions of the Fort Clatsop unit, the line segments may suggest a lower frequency of detected elk pellets in late winter, compared to fall. In both seasons, the south-central region appeared to have a high frequency of line segments with elk pellets recorded.

Figure B.2. Map of estimated distribution of elk pellets observed while en route between survey points, Fort Clatsop unit of Lewis and Clark NHP, late winter 2009-2012. Each line segment is colored to indicate whether elk pellets were noted (blue) or were not noted (orange). Years of data are presented adjacently.

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