Moose abundance, distribution, and demographic characteristics in eastern Washington
Progress report – Year 1
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SUMMARY

Moose (*Alces alces*) populations have been increasing in Washington State since the 1920's. The Washington Department of Fish and Wildlife (WDFW) began offering opportunities to hunt moose in 1977 and populations have continued to increase along with public interest in wildlife viewing and hunting opportunities. The WDFW implemented aerial counts in 2002 to better monitor population trends and establish minimum population levels in districts 1 and 2. Though such surveys provided rough estimates of abundance, they were insufficient to meet population monitoring objectives established by WDFW in the 2009-2015 Game Management Plan. The Wildlife Program WDFW identified obtaining better estimates of moose abundance and more precise estimate of population trend as Initiative #14 for the 2013-15 Wildlife Program Plan Charter. During winter 2013-2014, we began testing the efficacy of an aerial mark-recapture distance sampling approach (MRDS) to provide a standardized and repeatable survey protocol appropriate for a large-scale estimate of moose populations in northeast Washington. This document overviews preliminary results obtained during sampling in winter 2013-14.

In autumn 2012, WDFW began working with the University of Montana on a 3-plus-year study of moose demography in study areas north of Spokane. The objectives of this study are to understand the factors controlling adult female survival and calf recruitment as this increasing population approaches carrying capacity and deals with a new predator to the area: the wolf. We provide a brief overview of progress to date on the study. We also provide brief updates of what we've learned regarding internal parasites that may affect moose in Washington, recent range expansion statewide, and characteristics of moose captured in conflict situations in the greater Spokane area.

I. Moose abundance in northeastern Washington

Moose began colonizing northeast Washington in the early 20th century and have experienced a gradual expansion in both range and population over the last century. The Washington Department of Fish and Wildlife (WDFW) began offering opportunities to hunt moose in 1977 with a 3-tag lottery. Since that time, populations in northeast Washington have continued to increase along with public interest in wildlife viewing and hunting opportunities. The WDFW implemented aerial counts in 2002 to better monitor population trends and establish minimum population levels in Districts 1 and 2. Though such efforts provided rough estimates of abundance, precision was insufficient to meet population monitoring objectives established by WDFW in the 2009-2015 Game Management Plan (WDFW 2009; Harris et al. in review). In winter 2013-2014, WDFW began testing the efficacy of a line transect-based, aerial mark-recapture distance sampling approach (MRDS; Borchers et al. 2006) to provide a standardized and more precise survey protocol that would allow for regional- and district-level estimates of moose in northeast Washington.

Survey area

Surveys were conducted in northeastern Washington State (Fig. 1), primarily in the southeast portion of District 1 (Colville) and northeast portion of District 2 (Spokane). Land

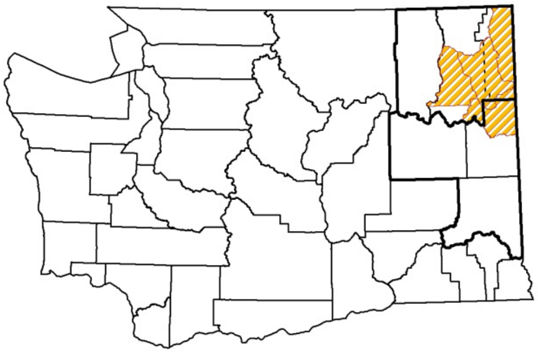


Figure 1. Survey area (shaded yellow) within WDFW districts 1 and 2 (bolded, District 1 top, District 2 bottom) in NE Washington State.

cover is generally characterized by agriculture and riparian areas at lower elevations and dense coniferous forests interspersed with active timber harvest at higher elevations (400 m – 1,800 m). Average temperatures range from -7°C in January to 30°C in July.

Methods

Sampling Design

Because moose habitat in District 1 encompassed a much larger area than District 2, selection of survey blocks was adapted to meet the objectives of each. Survey units in District 1 were identified by subdividing three general management units (GMUs) into smaller watersheds using the watershed tool in ArcMap 10.1 (ESRI, Redlands, CA). Watershed units were stratified by biologists' *a priori* opinions of the relative density of moose (high, medium, and low), and final survey blocks were selected via a random selection of high-, medium-, and low-density stratum blocks, based on their geographic location within each GMU. Survey units in District 2 encompassed the majority of available moose habitat in two small GMUs.

All potential transects were spaced 1 km apart in District 1, and 500 m apart in District 2. (We used higher intensity sampling in District 2 because the total area was smaller and thus we were concerned that sample sizes would be too low if using the 1 km spacing) To ensure independence among surveys flown in District 2, we surveyed only transects spaced at 1-km intervals during any single day, returning at least 1 day later when surveying alternately (500m) spaced transects. Transects varied in length depending on available habitat and survey unit size (range = 2 km – 29 km).

Survey Protocol

Surveys were conducted using a Robinson R44 helicopter during January-March 2014. We considered acceptable survey conditions to be days with low winds (<10 mph), temperatures below 2°C, and sufficient snow to cover stumps and low-lying vegetation in open areas. The pilot was instructed to maintain an altitude of approximately 400 ft. AGL (above ground level) and air speed of approximately 40 mph during all survey periods.

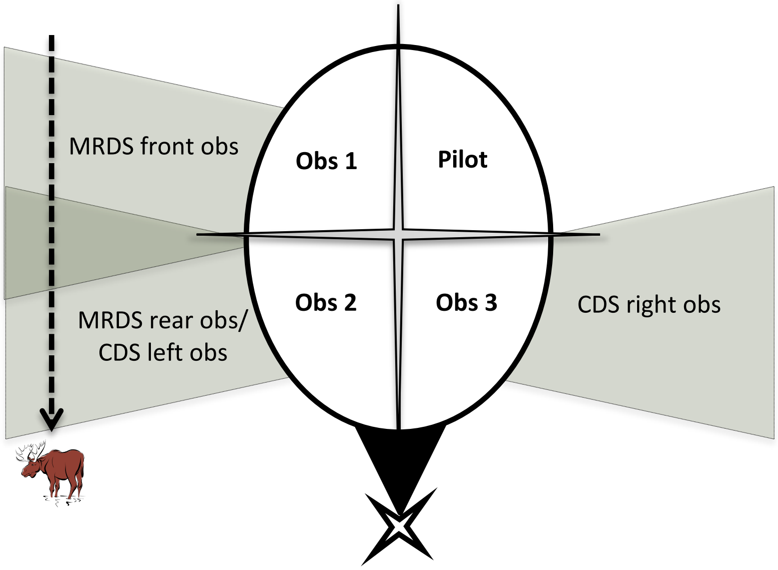


Figure 2. Observer position and viewshed (shaded polygons) during MRDS aerial moose surveys. Observers calibrate their detection viewsheds for mark-recapture using a landmark (the moose) to determine when Obs 1 should assume Obs 2 missed an object and indicate a detection.

Survey protocols for each observer depended on their position in the aircraft (front-left [obs. 1], rear-left [obs. 2], and rear-right [obs. 3]; Fig. 2). To maintain independence between detections made by observers on the left side, each survey session began with a short calibration exercise. Both observers first identified a fixed landmark ahead of the aircraft, but visible to both, and instructed the pilot to maintain a constant flight vector. The rear observer then called off the point at which the landmark (represented by a moose in Fig. 1) was no longer visible to them and the front observer noted the position of the landmark relative to their field of view. We initially used a visual barrier (cloth curtain) to ensure independence of observations made by both left observers. However, we later discontinued use of the visual barrier when it became clear that observers could not tell when a moose was detected by another observer until verbally notified.

For each survey, Observer 3 (designated note-taker and GPS-recorder) recorded start and end time, temperature, wind speed, general weather conditions, and sighting conditions (good, fair, or poor based on snow conditions, precipitation, and cloud/fog cover). During a survey, all observers continuously scanned for moose within their view shed across all distances up to approximately 500 m, however, the primary focus was on obtaining the largest number of detections in the survey area nearest the line (<200 m). The front-left observer called out detections only if the left-rear observer did not detect it while it was in their field of view. Rear observers on both sides called out detections only after the aircraft had passed the point at which the animal observed was perpendicular to the flight line to ensure estimation of perpendicular distance during post-processing was possible. Once a detection was called, the observer(s) then assisted the pilot in navigating to the detected animal and site of the original detection (if different) to collect further information. We then flew over the animal(s) and recorded the GPS location of the detection, which observer(s) saw it, moose activity when first observed (bedded, standing, walking or running) group size, age and sex of each moose observed (the latter based on presence of a white vulvar patch), percent snow cover and canopy cover within ~10 m of the location, cumulative proportion of each moose observed (e.g., 0.5 = ½ of 1 moose, 1.5 = 1 whole moose and ½ of another), and collar color, if present. If both left side observers detected the same group, only the covariates collected by the front observer were retained.

Distance sampling analysis

Because we had double-observers on the left side of the aircraft only (Observer positions 1 and 2), we estimated the mark-recapture correction using the encounter history for the left side only using the MRDS engine in Program Distance 6.0 (Thomas et al. 2010). To produce an observer-specific correction value using MRDS, all models included observer-position as a covariate. We used χ^2 tests to test that left (invisible under the helicopter) and right (far from the line and thus small sample size and variable) truncation values used for detection functions were supported by the data, and evaluated the effects of transect-level covariates including temperature, wind speed, and sighting condition (good, fair, poor) using Akaike's information criterion (AIC; Burnham and Anderson 2002).

To estimate probability of detection and density, we conducted a conventional distance sampling (CDS) analysis using rear-observer data only (obs 2 and obs 3; Fig.1) and incorporated the MRDS correction as a multiplier (the standard error of the multiplier also enters calculations made by program DISTANCE, using the delta method (Buckland et al. 2001:53)). We also compared corrected models using the multi-covariate distance sampling (MCDS) engine. Candidate MCDS models included the transect-and observation-level covariates temperature, wind speed, sighting condition, activity (bedded, standing, walking, running), percent moose seen, percent snow cover, percent vegetation cover, and a priori presumed density strata (high, medium, low), and were compared using AIC.

Preliminary results

We completed 175 line-transect surveys during 7 non-consecutive survey days (effort = 1,924 km; Fig. 3) that covered District 1 (*n* = 89, effort = 1,200 km) and District 2 (*n* = 86, effort = 724 km). Overall, 234 moose were counted during 132 independent detections including bulls (*n* = 74), cows (*n* = 108), calves (*n* = 44), and adults of unknown sex (*n* = 12). Of the 42 cow-calf pairs observed, twins were recorded on 2 occasions.

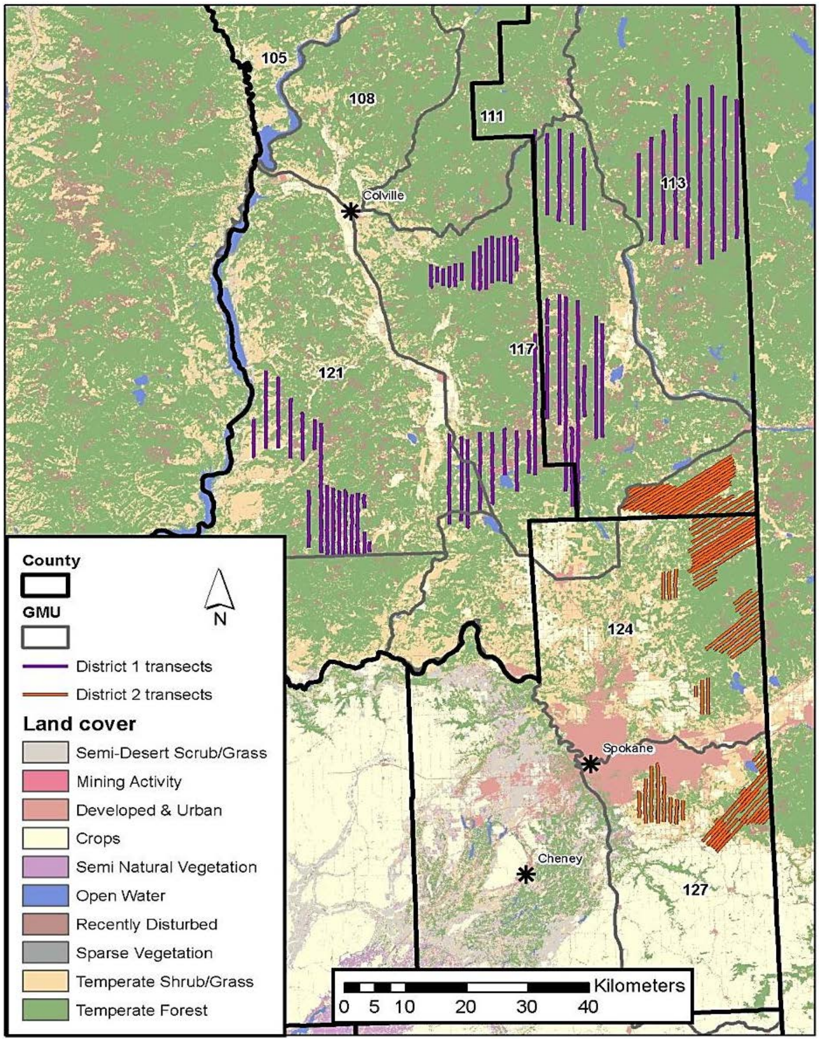


Figure 3. Transects flown during MRDS moose survey in northeast WA, 2014.

Mark-recapture portion (correcting for imperfect detection on the line)

The best MRDS model fit was used a left (invisible, under the helicopter) data truncation of 50 m and a right truncation of 300 m, yielding 66 detections for analysis. Chi-squared tests suggested no reason to reject the detection function fit with these truncations. (χ^2= 7.5, P = 0.48, df = 8). The most parsimonious model was a half-normal function with no adjustment terms and included percent cover (ΔAIC of alternatives was 0.58 – 4.0). Of the 66 detections, 12 were missed by the Observer 1 and 21 were missed by Observer 2, indicating that Observer 2 detected moose seen by Observer 1 at a rate of 83.5% (CV = 11.5%, see Appendix 1 for additional details). Thus, for subsequent CDS and MCDS analyses, the multiplier (G_0) accounting for imperfect detection on the transect line (i.e., ~ 50m from directly under the helicopter) was set at 1.1976, with its standard deviation at 0.1379 (and df set at zero).

Table 1. Mark-recapture distance sampling models for predicting the conditional detection rate between front and rear observers during aerial moose surveys in NE Washington, 2014. Top models are shown with number of estimable parameters (K), model log-likelihood (LL), change in Akaike's Information Criterion (Δ AIC), and model weight (w_i). Models tested were either half-normal (HN) or hazard-rate (HZ) with additional covariates indicated (% cover = percent forest canopy cover within 10m radius of moose, as estimated while flying over the moose; sight = ranked sighting conditions on transect; temp = ambient temperature as recorded by the helicopter during transect; wind = average wind-speed as recorded by in the helicopter during transect).

Rank	**Model components**	**K**	**LL**	**Δ AIC**	w_i
1	HN: Observer-position + % cover	3	-421.53	0.0	1.00
2	HN: Observer-position + % cover + sightability	4	-419.82	0.6	0.73
3	HN: Observer-position	2	-422.90	0.8	0.69
4	HN: Observer-position + sight	3	-421.16	1.3	0.53
5	HZ: Observer-position	2	-422.35	1.6	0.44
6	HN: Observer-position + temp	3	-422.66	2.3	0.32
7	HN: Observer-position + wind	4	-422.71	2.4	0.31

Density estimation

We used the same truncation values for the CDS and MCDS analyses, yielding 99 detections. The most parsimonious model was a uniform function with two adjustment terms (ΔAIC of alternatives was 1.22 – 5.3). Inclusion of covariates in numerous MCDS analyses failed to improve model fit (Table 2).

Table 2. Multi-covariate distance sampling models (adjusted for imperfect detection on the line and moose group size) estimating density of moose during aerial moose surveys in NE Washington, 2014. Top models are shown with number of estimable parameters (k), change in Akaike's Information Criterion (Δ AIC), density estimate (D), and upper and lower 95% confidence intervals. Models tested were uniform with adjustments (UN), half-normal (HN), or hazard-rate (HZ) with additional covariates indicated (% cover = percent forest canopy cover within 10m radius of moose, as estimated while flying over the moose; sighting condition = ranked sighting conditions on transect; temp = ambient temperature as recorded by the helicopter during transect; wind = average wind-speed as recorded by in the helicopter during transect). In all cases, data were truncated at 50 and 300 m; means are presented for data post-stratified by WDFW district.

Rank	Model components	k	Δ AIC	D	Lower 95%	Upper 95%
1	UN: no covariates	1	0.0000	0.265	0.186	0.377
2	HZ: no limit on adjustment terms, no covariates	2	0.6630	0.232	0.163	0.330
3	HN: no covariates	1	1.6100	0.214	0.142	0.322
4	HN: % cover	2	3.3030	0.256	0.197	0.333
5	HN: temperature	2	3.3040	0.257	0.198	0.334
6	UN: sighting condition	2	3.4440	0.254	0.196	0.330
7	UN: wind	2	3.5559	0.255	0.196	0.331
8	HN: temperature and wind	3	5.3020	0.256	0.197	0.333

The model estimated probability of detection ($\hat{p}$) was 0.58 (SE = 0.045, 95% CI: 0.480–0.645), and the effective strip width was 166.9 m. Mean group size was 1.43 moose (SE = 0.075) There was no evidence of cluster size bias, (slope of cluster size on distance β = 0.372, SE = 0.206, t = 1.81); thus, mean cluster size was used to estimate density of individual animals. The detectability-corrected estimate of moose density, pooled across all presumed density strata was 2.65 moose/ 10 km^2 (SE = 0.478 moose /10 km^2; 95% CI: 1.86 – 3.77; CV = 18.1%). Approximately 41% of the uncertainty in this estimate derived from the mark-recapture portion of the procedure, 34% from variance in the encounter rate, 17% from variance of the detection function itself, and only 8% from variance of moose group size. At first glance, this density appears considerably lower than many in the published literature; it should be borne in mind that this density applies over a large area that includes areas of poor moose habitat. Publication of abundance estimates will await additional surveys (ongoing, January-February 2015), as well as a more comprehensive analysis employing methods of (Nielson et al. 2014).

II. Moose distribution in Washington State

Although the colonization and increase of moose in the northeastern portion of Washington has been well documented (Base et al. 2006, Harris et al, in review), WDFW had not formally attempted to document moose distribution statewide prior to 2012. In late 2012, WDFW initiated a web-based citizen reporting tool, allowing observations to be mapped and documented (and for photographs to be uploaded for confirmation). To date, we've received over 300 credible observation reports. Because we have no way to account for variable observer effort or duplicate observations of the same animals, we cannot use this tool to estimate abundance or trend. However, we can gain a qualitative picture of what appears to be a gradual expansion of moose from northeastern Washington into other areas of the state. Notable are signs of an increase in Okanogan County to the west, documented residence as far west as the Pacific Crest in North Cascades National Park (and even a few observations west of the divide), and in the Blue Mountains to the south (Fig. 4). We continue to receive reports of moose traveling through unusual habitats (e.g., crop fields far from forested habitat). This tool will help us allocate resources toward formal moose surveys in future years.

III. Problem moose in suburban and/or agricultural settings

Since 2005, WDFW regional staff in Spokane have documented moose encountered in conflict situations with people. A total of 107 animals are recorded has having been captured in such settings; 4 were either euthanized at the scene or died. The remainder were released at various off-site locations and ear-tagged. Of 101 animals for which sex was recorded, 58 were females (8 calves, 21 'juveniles', and 28 adults), and 43 were males (7 calves, 15 'juveniles', and

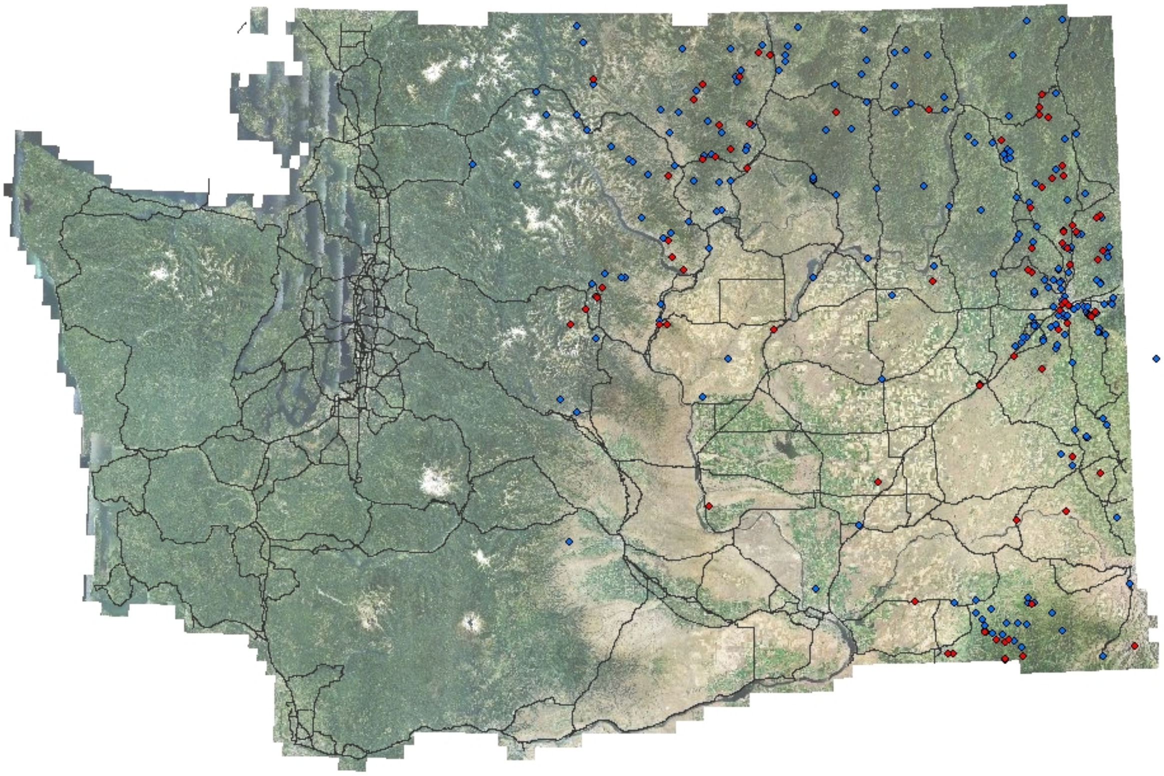


Figure 4. Locations of moose observed by WDFW staff and the general public, as reported on WDFW's web-based reporting system, during 2013 (blue) and 2014 (red). Moose distribution in northeastern Washington is under-represented because we discourage reporting from areas where moose distribution is well known; observation locations also likely reflect biases related to human presence and moose visibility.

19 adults). Seventeen animals were subsequently recovered dead. Fig. 5 provides year and month breakdown of these conflict actions. Incidents were apparently most common during the winter months of January/February, and the early summer months of May-July.

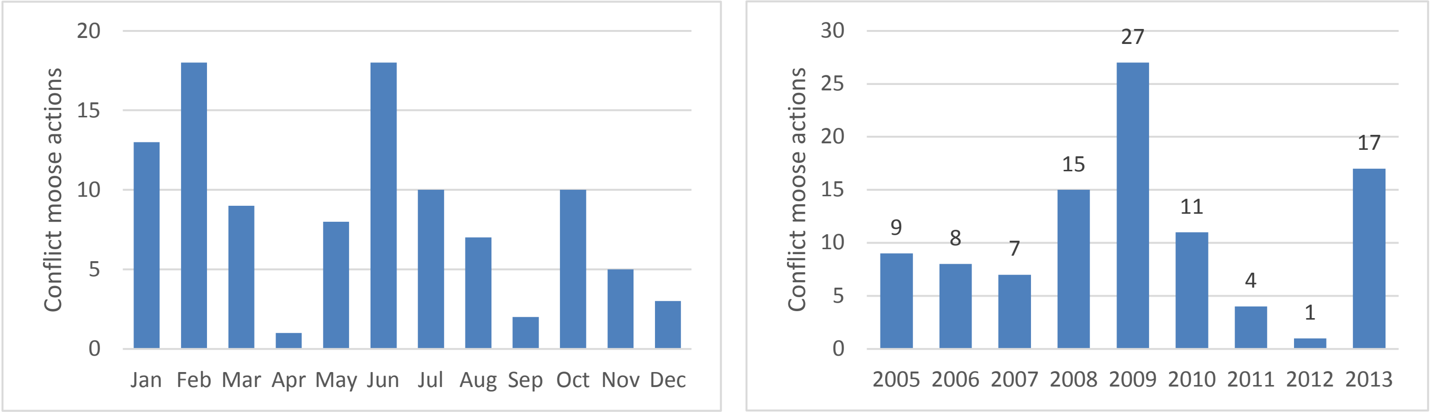
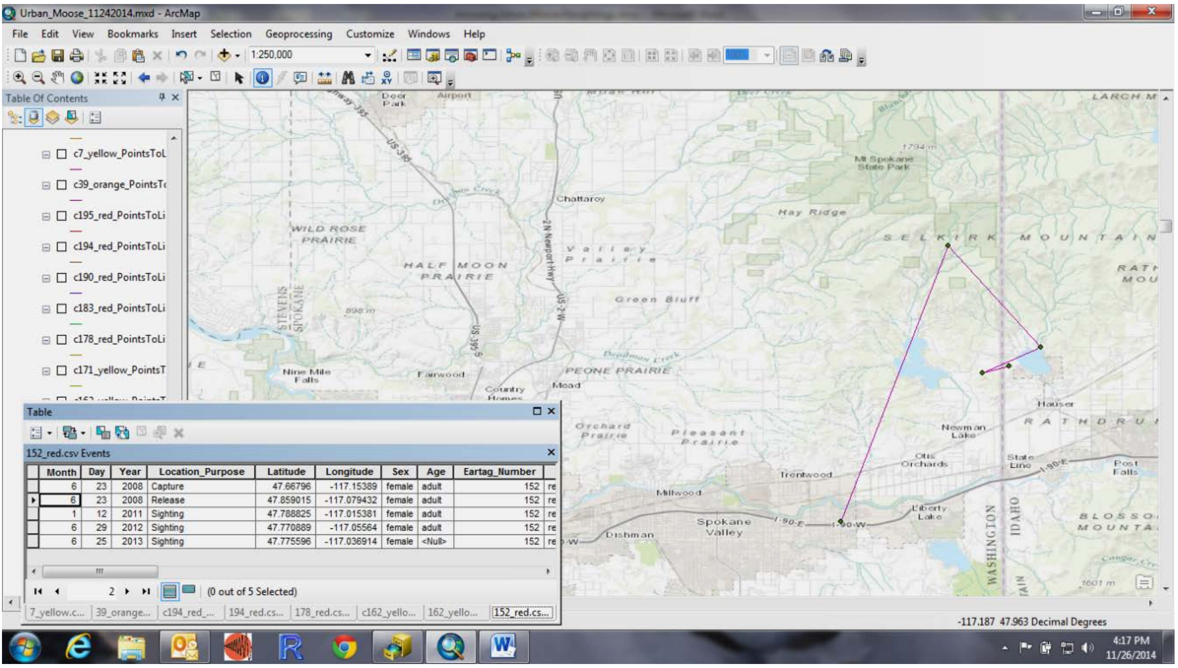


Figure 5. Left-hand panel: Conflict moose actions recorded by Spokane regional WDFW personal, 2005-2013, by month. Right-hand panel: Conflict moose actions recorded by Spokane regional WDFW personnel, 2005-2013 by year.

It should be noted that the winter of 2008-09 was exceptional, in that the Spokane area (where most problem moose issues arise) recorded the deepest snowfall in recent history. This likely accounts both for the evident spike in conflicts recorded during 2008-09 (Fig. 5, right-hand panel) as well as the prevelance of actions during January-February (left-hand panel). Excluding this anomalous year, most conflicts occur in late spring/early summer, or autumn. As sample size increases (and additional animals can be instrumented with GPS collars), we will conduct additional analyses on these data to better understand situations in which moose find themselves uncomfortably close to people, and to better guide our responses. Initially, it appears that at least 3 patterns of post-release behavior have been seen (based on the sparse data available from incidental observations and reports of ear-tagged moose): 1) animals that evidently remain relatively close to their release site for > 1 year (e.g., adult female 152, Fig. 6a); 2) animals that travel widely following release, but for which there is no evidence that they again become involved in a human-conflict situation (e.g., adult female 178, Fig. 6b); and 3) animals that return to close to their capture location, and need to be relocated a second time (i.e., 'repeat offenders' e.g., juvenile male 113, Fig. 6c).

A.

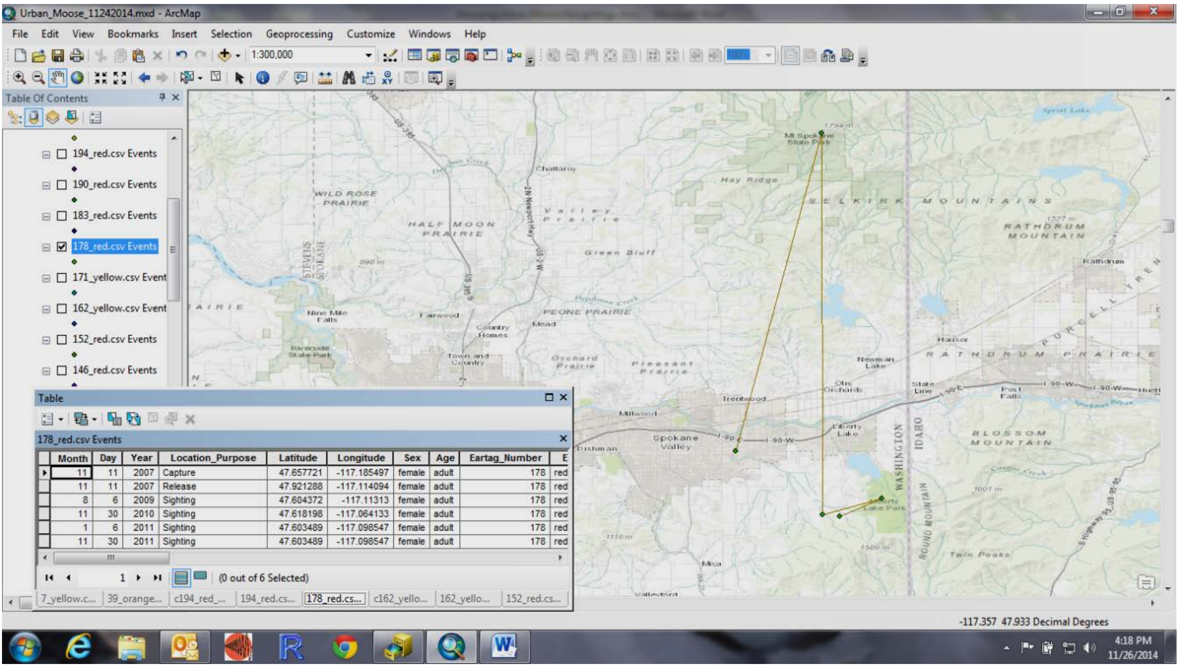


152_red.csv Events

Month	Day	Year	Location_Purpose	Latitude	Longitude	Sex	Age	Eartag_Number	
6	23	2008	Capture	47.66796	-117.15389	female	adult	152	re
6	23	2008	Release	47.859015	-117.079432	female	adult	152	re
1	12	2011	Sighting	47.788825	-117.015381	female	adult	152	re
6	29	2012	Sighting	47.770889	-117.05564	female	adult	152	re
6	25	2013	Sighting	47.775596	-117.036914	female	<Null>	152	re

(0 out of 5 Selected)

B.

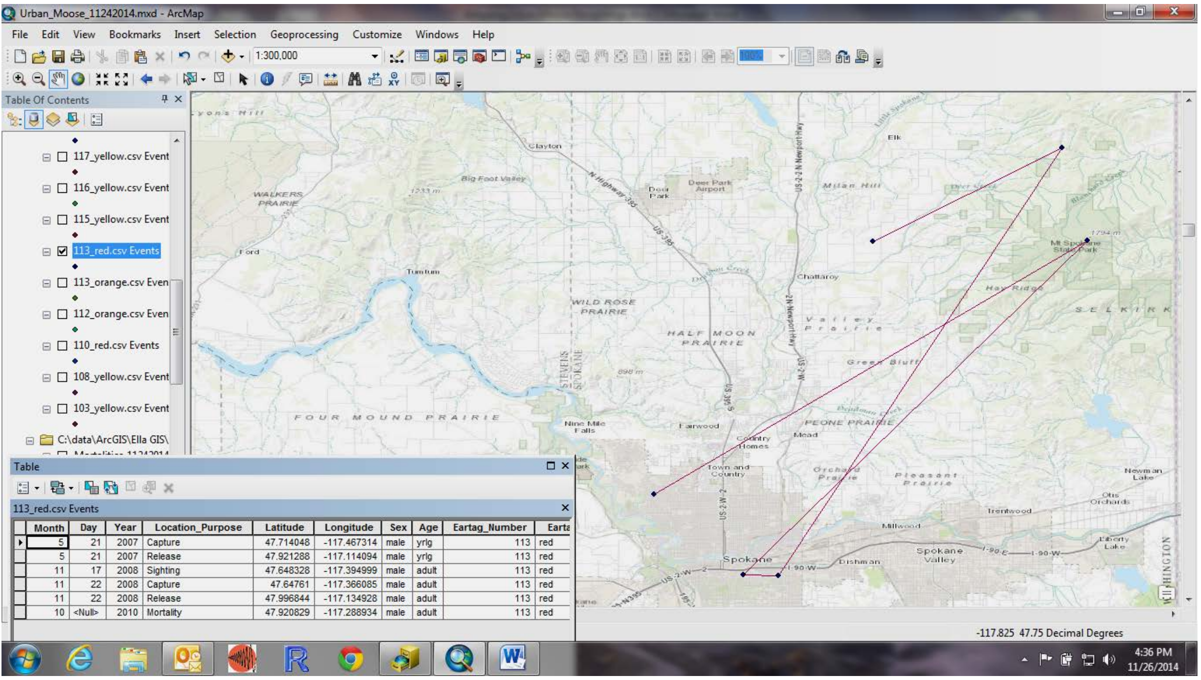


178_red.csv Events

Month	Day	Year	Location_Purpose	Latitude	Longitude	Sex	Age	Eartag_Number	E
11	11	2007	Capture	47.657721	-117.185497	female	adult	178	red
11	11	2007	Release	47.921288	-117.114094	female	adult	178	red
8	6	2009	Sighting	47.604372	-117.11313	female	adult	178	red
11	30	2010	Sighting	47.618198	-117.064133	female	adult	178	red
1	6	2011	Sighting	47.603489	-117.098547	female	adult	178	red
11	30	2011	Sighting	47.603489	-117.098547	female	adult	178	red

(0 out of 6 Selected)

C.



Table

113_red.csv Events

Month	Day	Year	Location_Purpose	Latitude	Longitude	Sex	Age	Eartag_Number	Earta
5	21	2007	Capture	47.714048	-117.467314	male	yrlg	113	red
5	21	2007	Release	47.921288	-117.114094	male	yrlg	113	red
11	17	2008	Sighting	47.648328	-117.394999	male	adult	113	red
11	22	2008	Capture	47.64761	-117.366085	male	adult	113	red
11	22	2008	Release	47.996844	-117.134928	male	adult	113	red
10	<Null>	2010	Mortality	47.920829	-117.288934	male	adult	113	red

Figure 6. Movements of 3 ear-tagged moose initially captured in conflict situations near Spokane, WA, 2006-08. A. Adult female 152 released near Mt. Spokane State Park June 2008, seen only in the Hauser Lake area, most recently June 2013. B. Adult female 178, released near Mt. Spokane November 2007, next observed near Mica Peak south of I-90, August 2009. C. Yearling male 113, released near Mt. Spokane May 2007, captured again in Spokane urban area November 2008 and released north of Mt. Spokane.

IV. Parasite testing from available carcasses

During hunting season 2013, WDFW began asking hunters to provide heads and/or carcasses to allow inspection for evidence of the arterial worm, *Eleaophora schneideri*. This collection continued during hunting season 2014. We have supplemented hunter kills with opportunistically obtained samples taken from road-killed animals and other mortalities. In calendar year 2013, WDFW inspected 12 animals; in calendar year 2014, we inspected 23 more individuals, 5 of which were not in condition to allow reliable assessment. We have yet to find evidence of *E. schneideri* in Washington moose (*n* = 35). In addition, we sent the carcasses from 2 moose euthanized in October 2013 to the Washington Disease Diagnostic Laboratory (WADDL) at WSU for inspection for the possible presence of *Parelaphostrongylus tenuis*, thought not to occur west of the Great Plains. These moose were evidently blind, and reported as engaging in circling behavior similar to that typically seen among moose infected with *P. tenuis*.

For one animal, necropsy revealed no evidence consistent with parasitic infection from either *E. schneideri* or *P. tenuis*; for the other, results were suggestive of parasite infection, but specific pathogens were not found; in neither case was condition of the head optimal for diagnosis. We suspect that some moose in northeastern Washington may suffer from some form of conjunctivitis (although have not yet obtained definitive evidence of this). Beginning in winter 2014-15, both UM and WDFW staff have begun collecting fecal pellets from white-tailed deer (*Odocoileus virginianus*). Attempts will be made to apply methods suggested by Slomke et al. (1995) and Forrester and Lankester (1997) to confirm presence/absence of *P. tenuis* in northeastern Washington.

V. Determinants of population trend of moose in northeastern Washington

We believe the current, positive rate of growth for northeastern Washington moose is likely to change in the near future, either to an approximate leveling-off, or possibly decline to a new, lower equilibrium level. Our expectations are based on the following: 1) wolves continue to increase in density in NE Washington; the population-level effect of their predation on moose is currently unknown; 2) changes in forest practices in NE Washington have generally moved forests into older age-classes that produce less forage for moose; 3) moose have recently undergone declines in other areas (Minnesota, NE Wyoming, northwestern Montana, eastern Panhandle region of Idaho) for reasons that are imperfectly understood, but probably include diseases, parasites, and possibly direct effects of a warming climate. Even in the absence of these three factors, we would expect moose density to exert an effect through increased resource competition, and thus population growth to cease. Alone or in combination, these factors may affect recreational hunting. However, equipped only with estimates of population size and trend, we will be limited in our ability to take appropriate actions to limit the expected moose decline without understanding the relative contribution of each of these possible causes.

Primary objectives of the multi-year study are:

a. Document survival rates of cows and calves for input into statistical reconstruction models, demographic projection models, and allowable harvest models;

b. Test whether survival rates of cows and calves differ in areas of 1) high vs. low wolf density, 2) older vs. young forest age-structure, 3) other habitat characteristics quantifiable using remote sensing;

c. When possible, document (or infer) causes of mortality for cows and calves, and relate these to relative predator abundance, habitat conditions, cow body condition, climatic variables, hunter harvest pressure and health status;

d. Document calf production for input into statistical reconstruction models, demographic projection models, and allowable harvest models;

e. Test whether calf production rates and cow body condition indices differ in areas of 1) high vs. low wolf density, 2) older vs. younger forest age-structure, and 3) other habitat characteristics quantifiable using remote sensing.

A. Study areas.

In late 2013, WDFW began working with the University of Montana (UM) to better understand determinants of moose population dynamics in northeastern Washington. WDFW delineated two coarsely-defined study areas (briefly referred to as “northern” and “southern” study areas (Fig. 7).

Much of the southern area consists of industrial timber-land and/or residential subdivisions. Considerable timber harvest activity is continuing to provide a range of seral conditions that provide forage for moose. This area has had consistently high moose density and hunter harvest over the past 10 years. It has relatively low wolf presence; because of the proximity to populated areas and heavily used roads, we expect wolf density to remain low-to-moderate in this study area over the next few years.

The northern study has had consistently high moose density and hunter harvest over the past 10 years. It has relatively high wolf presence; because of the distance to populated areas, we expect wolf density to remain moderate-to-high in this study area over the next few years. This area also may have a few grizzly bears. The northern area is primarily managed by the Colville National Forest, and forest practices over the past few decades have de-emphasized clear-cutting. Considerable forest maturation in this area is likely to be reducing the availability of browse favored by moose

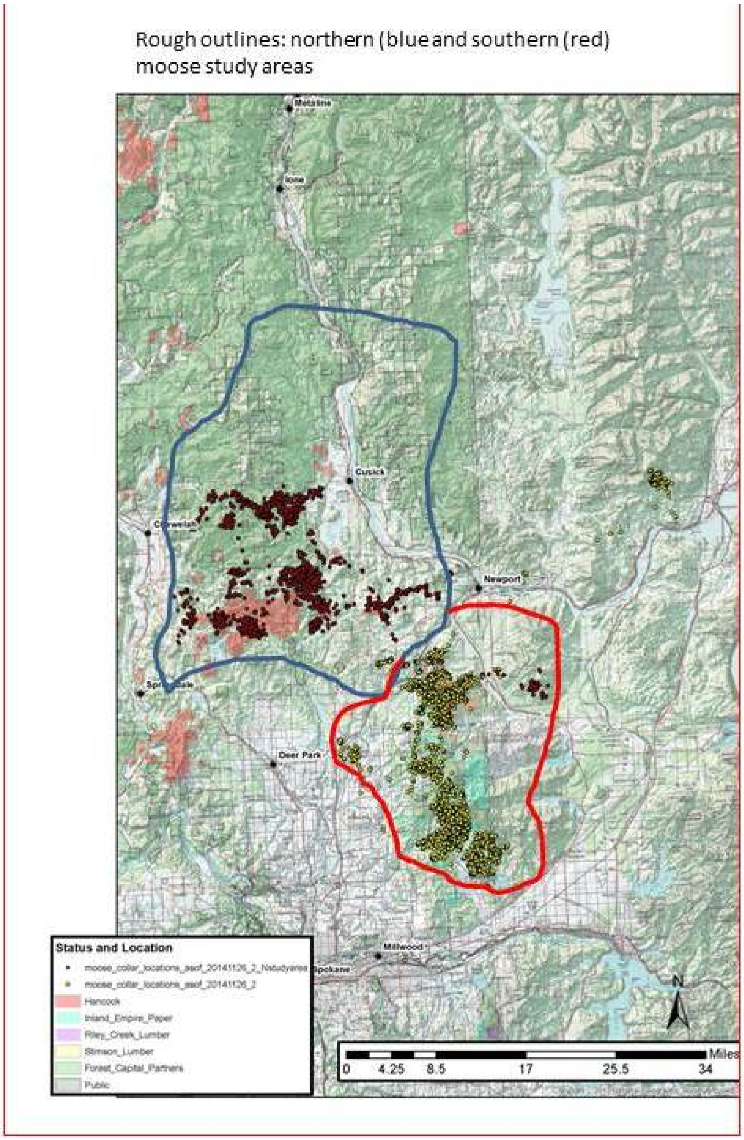


Figure 7. Approximate study area boundaries (blue polygon: northern, red polygon: southern), with moose GPS location points obtained prior to December 2014.

B. Capture and marking

Our initial study plan called for radio-marking up to 30 adult female moose in each of the 2 study areas. In Decembers 2013 and 2014, WDFW contracted with pilot Jess Hagerman of Northwest Aviation (Olympia, WA), and used its own staff, along with contract biologist Dr.

Rachel Cook, to capture, assess body condition, and fit adult female moose with GPS-Survey collars (Vectronics Aerospace, Berlin, Germany). We programmed collars to generate and transmit to satellites locations every 23 hrs, and to send a mortality advisory after a 9-hour delay. Moose were darted from a Bell Jet Ranger with a combination of Carfentanil and Xylazine (exact doses varied during the period), and later reversed using naltrexone (administered half IM and half IV) and tolazoline (IV). Except where body position and/or concerns about animal health prevented it, for each moose we made a general inspection of body condition, including hair loss due to parasites, measured total girth and total length (tip-of-nose to tip-of-tail not including hair), scored body condition using a previously-developed elk index, estimated percent body fat using a portable ultra-sound machine, estimated pregnancy using ultra-sound and/or rectal palpation, assessed lactation status (capture crews recorded presence of calves at capture), extracted blood for presence of pregnancy specific protein B (BioTracking LLC, Moscow, ID), extracted an incisor-from canine tooth for ageing (after first injection of a Marcaine local anesthetic), and provided prophylactic antibiotics. To minimize chance of cross-infection, we used clean, non-re-useable blindfolds to cover eyes of all captured moose. We attached a colored ear-tag (including information on edibility of the meat should the animal be harvested). During December 2013 captures, we also obtained a tissue sample via ear-punch for the Montana FWP-led phylogenetics study. In both years, we collected external parasite samples opportunistically.

During summer 2014, UM and WDFW personnel conducted ground-based direct observations of cows to determine calving status, supplemented when useful by helicopter-based observations. Graduate student James Goerz began pioneering the use of strategically-placed remote cameras to estimate calf presence, as well as citizen-science reporting, with good success (Figs 8, 9).

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Figure 8. Cow and calf moose, collared in December 2013, captured by remote photography by UM graduate student James Goerz, mid-summer 2014.

Figure 9. Cow and calf moose, collared in December 2013, during helicopter survey, June 12, 2014, to assess calving status. Photo by Sara Hansen.

C. Progress-to-date

During December 16-20 2013 we marked 27 adult cows (12 north, 15 south). We sustained one capture-related mortality. During December 2-6 2014 we marked an additional 24 adult cows (14 north, 10 south; no capture-related mortalities). Thus, for adult mortality and calf recruitment estimates, we have total *n* = 51 (26 north, 25 south). In addition, we captured and fitted an ear-tag (but not a radio-collar) to one female calf in the southern area.

We obtained chest girth measurements on 30 animals and total length measurements on 40 animals. Girths of measured moose averaged 174.9 cm (SD = 11.9, min = 141, max = 208); length measurements averaged 263.5 cm (SD = 13.5, min = 224, max = 285). We obtained maximum rump fat measurements from 39 animals, and loin muscle measurements from 35. Maximum rump fat depth varied from 0.0 to 2.5 cm ($\bar{x}$ = 1.0, SD = 0.7), and loin muscle depth from 2.0 to 5.4 ($\bar{x}$ = 4.7, SD = 0.6). We documented the presence or absence of a calf at time of capture for 42 of the captured moose: half (21) were accompanied by calves, the other half were not. Two of the 21 were accompanied by twin calves (1 northern area in 2013, 1 southern area in 2014). We were able to document lactation status for 34 cows, of which 5 were recorded as actively lactating at time of capture. We estimated pregnancy using ultra-sonography for 29 animals: of these, 24 (83%) were pregnant. We obtained PSPB pregnancy estimates for 43 animals: of these 34 (79% were pregnant). We extracted teeth from 36 animals, and as of 1/28/2015, have ages from 16 animals captured in December 2013 (Matson's Lab, Milltown, MT). Ages varied from yearling to 10 years ($\bar{x}$ = 5.3, SD = 3.3). Analyses of these animal condition data will await arrival of the remaining animal ages. In general, we observed that cows accompanied by calves and/or lactating at time of capture were characterized by lower body fat measurements than those without calves, as expected.

During summer 2014, UM staff documented calves produced by 16 of the 25 adult cows that survived winter 2013-14, two of which had twins. Survival of calves through summer 2014 was evidently high: 17 of 18 were estimated to have survived through August 2014. As of early January 2015, evidence suggested the loss of a total of 6 calves (from 6 cows) from the total 18 monitored.

Using camera trapping, we were able to confirm the presence of at least 2 wolves within the central portion of our northern study area (near 49 Degrees North Ski Resort). Biologists from WDFW as well as the Little Pend Oreille NWR have confirmed the presence of several packs in the northern portion of the northern study area (near LPO NWR) and camera trapping efforts are currently in place to detect them as well. We currently have 12 cameras distributed across the study area (6 in each study area, north and south) in order to collect preliminary data on the type and extent of predation risk that moose are exposed to (Fig. 10). If this method provides sufficient data, we plan to expand the effort to 24 cameras (12 in each study area) in summer 2015 in order to understand potential factors affecting calf mortality.

A total of 5 deaths of collared females entering the study have been documented to date. Three of the 27 cows initially captured in December 2013 died of unspecified natural causes (but were known to have not been killed by predators); two in March 2014, one in October 2014. A fourth was legally harvested by a licensed hunter on October 25, 2014. One of the animals captured in early December 2015 died on approximately December 31, 2014 from undetermined causes.

Personnel from UM have collected 97 moose fecal samples from 27 individuals (adults and calves) to examine stress and pregnancy over time, and collected 23 white-tailed deer fecal samples from across the study area to assist with parasite/disease transmission monitoring.

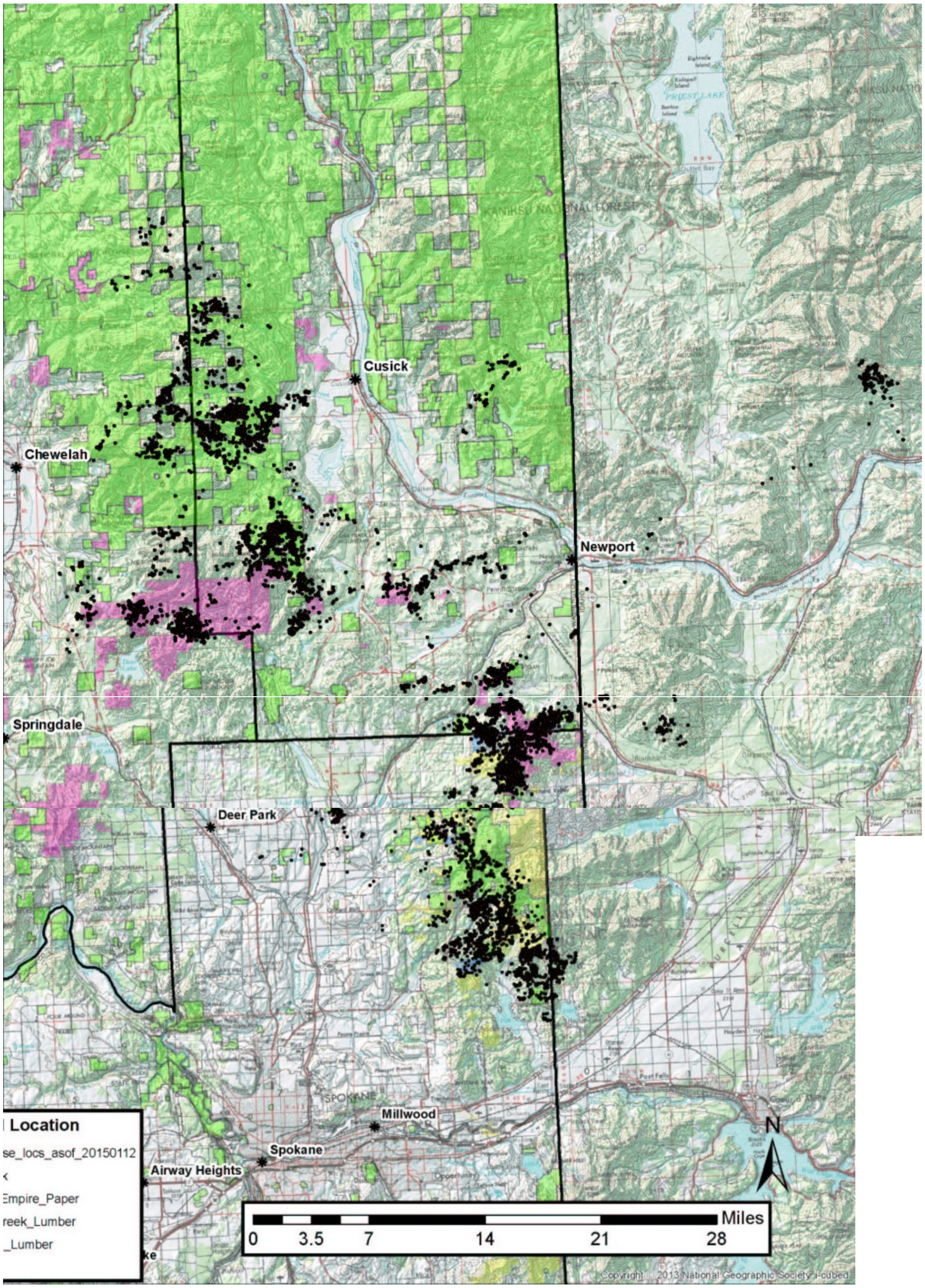

Figure 10. Accumulated locations of 51 adult female moose collared during December 2013 and December 2014, as of early January 2015.

Moose monitoring will continue without interruption throughout 2015 in order to track calf survival, collect fecal samples, and camera trap the study areas to understand predator distribution and composition.

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