Report on aerial surveys of tule elk (*Cervus canadensis nannodes*) in 2018–2019 in Bear Valley, Cache Creek, East Park, and Lake Pillsbury Tule Elk Hunt Zones

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SUMMARY

In 2018–2019, staff from the California Department of Fish and Wildlife (CDFW) in the North Central Region and Wildlife Branch conducted aerial surveys of tule elk (*Cervus canadensis nannodes*) from a Bell 407 helicopter in 4 elk hunt zones (i.e., Bear Valley, Cache Creek, East Park, and Lake Pillsbury) encompassing three elk herds (Cache Creek, East Park Reservoir, and Lake Pillsbury) in Colusa and Lake Counties. We used distance sampling and a stratified sampling design with two strata of elk use defined from 63,727 locations of 78 GPS-collared elk. Our minimum count for the entire survey area was 523 elk, including 316 adult females, 135 adult males, and 77 juveniles (<1-year old) and were greatest in Bear Valley (215 elk), followed by Lake Pillsbury (140 elk), Cache Creek (85 elk), and East Park Reservoir (83 elk). Population estimates from distance sampling were 252 (90% CI = 160–397) for Bear Valley, 144 (74–281) for Cache Creek, 109 (56–210) for East Park Reservoir, and 166 (91–302) for Lake Pillsbury. The average detection probabilities of elk by helicopter survey crews at the minimum (0%), mean (19%), and maximum (80%) levels of canopy cover were 0.92 (90% CI = 0.72–0.98), 0.84 (0.66–0.94), and 0.34 (0.20–0.57), respectively. The survey design likely resulted in population estimates that were biased low and we make recommendations for changes to future survey designs to mitigate that potential bias.

INTRODUCTION

The tule elk *(Cervus canadensis nannodes)* is a subspecies of elk endemic to California that was nearly extirpated, being reduced to as few as 3 animals, in the late 1800s (McCullough 1969; Meredith et al. 2007). Through intense management, which has included translocations and reintroductions, tule elk populations have grown to number >6,000 across 22 distinct Elk Management Units (EMUs) (Williams et al. 2004; CDFW 2018). Three tule elk herds have been established in Colusa and Lake Counties within the last 100 years and are managed within hunt zones in three EMUs (Fig. 1): the Cache Creek herd (established in 1922), the Lake Pillsbury herd (1978), and the East Park Reservoir herd (1992; CDFW 2018). While each herd has its own nuanced history, all are thought to have gradually experienced an increasing trend in both estimated population size and spatial distribution since their initial introduction or natural reestablishment (CDFW 2018). Limited harvest of each herd occurs annually, with a high rate of hunter success (CDFW 2018).

Periodic population surveys allow biologists to monitor population trajectories, determine demographic rates of herds, visualize habitat use and general health of animals, and locate areas of potential range expansion. Additionally, population monitoring provides data needed to inform levels of regulated harvest of game populations and address the increasing demand on the California Department of Fish and Wildlife (CDFW) to produce scientifically defensible and statistically robust population estimates rather than provide minimum counts (Nelson and Hooper 1975).

Traditionally, population monitoring of tule elk in Lake and Colusa Counties in northern California has been limited to minimum counts from ground and aerial surveys or incidental, non-systematic observations. These surveys were intended to serve as indices of abundance and herd composition and do not allow the production of statistically robust population estimates or error to be estimated using statistical methods (Bleich et al. 2001).

Starting in 2018, CDFW's North Central Region (NCR) and Wildlife Branch (WLB) coordinated to develop distance-sampling protocols to be used in aerial surveys of elk in the Bear Valley, Cache Creek, East Park Reservoir, and Lake Pillsbury EMUs. Initial efforts had low success, due to insufficient numbers of detections (i.e., number of elk groups encountered rather than total number of elk observed), which was a result of the biology of elk in the NCR; namely, elk are herd-dwelling animals that occur in clusters at relatively low densities across the landscape, group sizes tend to fluctuate spatially and temporally, which in turn affects detection probability (i.e., large groups are more likely to be observed and counted versus small groups or single individuals) (Williams et al. 2002).

In 2019, NCR and WLB again collaborated on surveys and doubled sampling efforts, by sampling each polygon twice, using the same protocols developed in 2018. The goal was to increase sampling efforts in 2019 and combine with the previous year's data to produce more precise, robust, and biologically meaningful population estimates.

SURVEY OBJECTIVES

1. Produce a minimum count for elk populations in the 4 EMUs comprising Colusa and Lake counties (i.e., Cache Creek, East Park, Bear Valley, and Lake Pillsbury Elk Management Units).
2. Estimate elk abundance, detection probability and test associations between detection probability and covariates of canopy cover, group size and survey year in these areas using distance sampling
3. Determine herd composition (age and sex ratios) of the elk populations in portions of the Cache Creek, East Park, Bear Valley, and Lake Pillsbury Elk Management Units.
4. Provide estimates of elk abundance from aerial surveys for comparison with estimates from fecal DNA monitoring techniques used in the Colusa-Lake Tule Elk Study (CDFW 2016)

METHODS

Study Area

The 5,723 km^2 study area encompasses three EMUs located in the Northern California Interior Coast Range (Fig. 1). The dominant habitat types include blue oak woodland, annual grassland, chamise chaparral, chamise and redshank chaparral, montane hardwood conifer, blue oak - foothill pine and agricultural lands(CDFW 2018). The primary land uses are cattle ranching and public lands reserved for wildlife-oriented recreation including hunting and wildlife viewing.

Survey Design

We adapted and applied aerial line distance sampling (Buckland et al., 2001, 2004) to survey for elk. To guide survey efforts, we referenced results from past aerial surveys, ground-based fecal-DNA monitoring surveys (Batter et al. 2020), and 63,727 location datapoints from 78 collared elk (39 bull; 39 cow).

Within the study area (Fig. 1), we mapped flight polygons (Fig. 2), which were stratified by areas known to support elk (known elk use polygons) and areas where elk presence is unknown (unknown elk use polygons). Polygons of known elk use included all 63,727 locations from 78 collared elk and a 1–5 mile radius buffer on the periphery of these locations. The buffer distance was based on adjacent habitat types, land ownership, and known landscape blocks. The buffer was intended to increase the likelihood of detecting elk that use the periphery of the core known elk use areas which might indicate if elk are expanding from their historic and known range.

We selected the entire known elk use stratum for surveying. We surveyed the area once in 2018, and twice, 6–11 days apart, in 2019. We performed replicate surveys in 2019 to increase precision in estimates of detection probability and abundance while allowing sufficient time between surveys to maintain independence of detection.

The unknown elk use stratum consisted of areas outside the known elk use stratum, regions predominantly made up of cultivated agricultural and timberlands (12% and 40% of the study area respectively). Given tule elk life-history traits (i.e., preference for open habitat), combined with exclusionary fencing on agricultural lands, and dense canopy cover that restricts visibility in timberlands, we largely excluded these areas from survey to increase efficiency (CDFW 2018). We did not sample the unknown elk use stratum in 2018, but sampled $n = 7$ randomly selected polygons in the unknown-use stratum for surveys in 2019.

In each selected survey polygon, we placed North-South oriented line transects at 800-meter intervals from boundary to boundary.

Data Collection

We flew surveys from December 3–6, 2018 and December 3–16 2019. Within each survey polygon, a contract pilot, from Air Shasta Rotor and Wing, flew a Bell 407 helicopter, approximately 40 m above ground level and followed the topography of the landscape. Airspeed was maintained at 30–40 knots unless vegetation or elk density dictated a change in speed. Flight crew chose to fly "doors on" in the rear cabin to reduce crew fatigue and increase safety. Helicopter doors were designed for aerial survey work and are convex to allow for unobstructed views of the ground including areas directly below the helicopter (on-transect).

Flight crew included a navigator/data recorder seated in the front passenger seat of the helicopter, and two observers seated in the back of the helicopter. Radio and automated flight followers tracked the flight from the ground. The navigator/data recorder was responsible for navigation, using Gaia flight navigation and tracking software (v2020.6) on an iPad Air 2 (Model A1567) and secondarily, a handheld Global Positioning System (GPS; Garmin GPSMAP 64st) unit as backup, and recording observations on the data sheet (Fig. 3). Observers in the backseat of the helicopter were responsible for counting total elk in a group, as well as group composition (“comping”), i.e., total number of bulls, cows, and calves. All helicopter personnel were expected to examine the landscape for elk and were responsible for helicopter safety.

Observers as well as the data recorder/navigator were instructed to visually scan for elk from 0-400m with frequent return to the centerline. Data recorder/navigator had an unobstructed view off the nose of the helicopter and often was able to call out elk directly on centerline as the helicopter approached. When a group of elk was observed, we collected data on the group, usually leaving the transect to do so. Observers counted the total number of elk present, then provided composition counts of bulls and calves. When needed, the pilot flew in close to the elk group to determine spikes. When possible, cow elk were counted last and, when coupled with bull and calf counts, provided confirmation of total group size. In addition, observers estimated the percent canopy cover of the group (COVER), a visual estimate of cover capable of concealing an elk (i.e., trees or high shrubs) in the area originally occupied by the elk group plus a 10-m radius buffer. Data observers estimated percent cover from 0–100% in increments of 5%, based on a reference schematic available to crew during flight.

We recorded the horizontal closest distance from the transect to the group or the data needed to calculate it, using one of three methods: 1) fly to the center-point of where the elk group was located upon initial sighting and record a GPS point using the navigation iPad or a handheld GPS (the primary method used), 2) circle the elk group and post hoc estimate group center in relation to the flight path, and 3) measure distance via a handheld rangefinder. If the group moved after initial sighting, we flew above the original sighting location and recorded this GPS point. When the primary method was not feasible due to terrain or safety, we employed the second method described. We used the handheld rangefinders for only a small number of observations.

Following survey flights, we measured distances by mapping the waypoints and flight lines on Google Earth Pro (v. 7.6.2, Google Inc. 2005) and calculated the perpendicular distance between the two. In most cases, the flight path was projected in a straight line because elk were observed ahead of the helicopter and we flew to the group centerpoint immediately to determine composition.

Data Analysis

We estimated population size using covariate distance sampling (Buckland et al. 2001, Buckland et al. 2004). In covariate distance sampling, the detection probability of an object is modeled as a joint function of distance from the observer to the object, and covariates associated with detection of the object. In clustered populations such as elk, the objects consist of groups of animals detected together. For analysis of our survey data, we adopted a half-normal detection model structure with detection probability = 1 on the transect line and scale parameter (σ) governing how rapidly detection declines with distance. To avoid overlap with other transects, we excluded detections occurring at distances >400 m.

We selected covariates for potentially explaining variation in the scale parameter. For concealing cover, we used two covariates. COVER was the ocular estimate of concealing cover described under Data Collection. We computed COVER50, the mean tree canopy cover over a 50 m radius of detection waypoints, from the LANDFIRE Existing Vegetation Cover database (LANDFIRE 2013). We also included the covariates SIZE for group size and YEAR for survey year.

We fit four single-covariate detection probability models (σ ~ COVER, σ ~ COVER50, σ ~ SIZE and σ ~ YEAR) and the null model (σ ~ 1) using maximum likelihood estimation via R statistical software (version 3.5.2, R Core Team 2019) and the Distance package (Miller 2017). Since COVER and COVER50 were likely to be collinear, we removed the corresponding model with the higher Akaike's Information Criterion (AIC) score from consideration (Burnham and Anderson 2002). We selected models with the lowest AIC and comprising at least 0.95 of cumulative model weight from the remaining subset (Burnham and Anderson 2002).

For population estimates in the high elk use stratum by EMU and total for the study area, we used model-averaging among selected models, and combined replicates by weighted average. Replicate weights were 0.5 for 2018 and 0.25 for each of the two 2019 replicates. Additionally, we model-averaged to obtain estimates of mean group size and detection probability for the study area. We computed standard errors and 90% confidence intervals for all estimates. To facilitate management and comparison to results from other surveys, we also computed a population estimate for the Bear Valley and Cache Creek EMUs combined.

We illustrated the predicted effect of concealing cover on detection probability. For COVER values of 0, 20, 50 and 80%, we computed the distance-detection probability curves as predicted by the COVER model. Then we computed the mean detection probability for groups conditional only on being present within the truncation distance of 400 m.

RESULTS

In the known-use stratum, we recorded 159 detections of elk groups, ranging in size from 1–120 animals (median = 4; Fig. 4). In both years and replicates, the highest counts were in Bear Valley followed by Lake Pillsbury, Cache Creek, and East Park Reservoir (Table 1). Cover at detected groups ranged from 0–80% with a mean of 19% (Fig. 5). For distance sampling, most distances to detected groups were measured using GPS data in Google Earth (85%) with the remainder by rangefinder in the field. We excluded three detections from the distance sampling analysis with distances >400 m; each of these detections was of a single animal.

The detection probability model with greatest support was σ ~ COVER which had 80% of the model weight (Table 2). We retained the COVER model and dropped COVER50 as COVER had greater support. We also retained the SIZE and null models for a total AIC weight of 0.954.

The two-year average population estimate for the high elk use stratum was 671 elk (90% CI = 498–903; Table 3). Coefficients of variation for EMU-specific estimates were all ≥0.28, while the CV for the total estimate was 0.18. Mean cluster size was 9.70 elk (90% CI = 7.46–11.94). For elk groups within 400 m of a transect, mean detection probability was 0.789 (90% CI = 0.667–0.875).

The detection probability model σ ~ COVER predicted a significant effect of concealing cover on detection probability (Fig. 6). While detection probability decreased with distance from the helicopter at all levels of COVER, it dropped off more quickly as COVER increased. The average detection probabilities at the minimum (0%), mean (19%) and maximum (80%) levels of COVER were 0.92 (90% CI = 0.72–0.98), 0.84 (0.66–0.94) and 0.34 (0.20–0.57), respectively.

DISCUSSION

This survey represents the first application of distance sampling for tule elk in the North-Central EMUs and an opportunity to evaluate methods for potential future surveys. Our findings on the effect of canopy cover on detection probability in the study area strongly suggest that our survey design and methods may be biased low for population size. The design of the current study required the assumption that detection probability was = 1 along the transect center line (distance = 0; Buckland et al. 2001). This meant that, although we allowed for missed animals further away from the transect, we did not allow for missing any at short distances. For example, if detection probability on the transect center line averaged 0.7, then expected values of population estimates were 70% of true. These estimates would have been further biased downwards by systematic under-counting of the number of animals in detected groups were it to occur.

While we do not know whether these biases occurred in our survey we had the conditions for them to occur. Previous aerial survey studies with elk have found imperfect detection and under-counting of groups both occur in areas with medium-to- dense canopy cover (≥40% cover) resulting in under-estimation of population size (McCorquodale et al. 2013, Cogan and Diefenbach 1998). In our survey, 27% of the known elk use stratum was covered by medium to dense tree canopies (LANDFIRE 2013). The highest ranked model predicted that 26% of elk groups occurred under this level of cover suggesting that elk are found in these areas. Furthermore, our modeling of survey data showed that overall detection probability was substantially lower in higher cover than in areas with less cover (Fig. 4). This cover effect may have included areas near the transect line resulting in a proportion of animals being missed there.

Additional biases may have also impacted our population estimates, not accounted for by our study. For example, Bleich et al. (2001) determined aerial detection of tule elk can be significantly affected by habitat type, specifically improved contrast between elk pelage and green conditions (increasing probability of detection) versus brown or dry conditions (decreasing probability of detection). While we attempted to sample during the same season across survey years to mitigate this type of effect, variation in ground cover condition coupled with a heterogeneous landscape likely affected contrast and thus detectability of elk within our survey area. Future surveys might consider integration of elk contrast with green/brown vegetation conditions as a factor in detection to better understand the impacts in this particular study area. This could be accomplished by defining and collecting a categorical variable for contrast between pelage and vegetation in the vicinity of each elk group, or by collecting a stand-in variable such as dominant vegetation type (Bleich et al. 2001).

We recommend that future distance sampling surveys in these elk management units be designed to estimate detection probability near the transect line rather than relying on the assumption that it is =1. Hierarchical distance sampling methods (HDS; Kery and Royle 2016) can be employed with a survey design that includes replicated sampling over a short period of time. HDS methods also allow more robust population estimation in areas with few or no detections as in the unknown elk use stratum in this survey.

Our surveys included sampling outside areas of the management units known to be frequently used by elk. The sample size was small with 106 kilometers of transects surveyed once compared to 1071 kilometers of transects surveyed 3 times in the known elk use polygons. Although we detected no elk on these units, our results did not rule out the possible presence of elk in this stratum in the period of the survey. Future surveys should utilize a habitat suitability model to guide surveys towards regions where elk would realistically occur in relation to established populations (Batter et al. 2020) and should increase sample effort in unknown use areas and ensure that all potentially suitable elk habitat is represented in the sampling frame without sacrificing survey time or efficiency.

We flew surveys from December 3–6, 2018 and December 3–16 2019 with 2019 replicates flown 6–10 days from first run due to weather-related delays. Survey dates are part of a larger statewide scheduling effort and attempted to maximize detection of elk and correctly assign elk age and sex. A December flight ensured that deciduous trees and shrubs did not have leaves and bull elk still held antlers. Additionally, in December there generally is some "green-up" prior to the survey. Green grass on the landscape likely increases detection probability because the tawny coat of an elk stands out better against a green background (Bleich et. al 2001).

The orientation and survey distance of transects was selected due to the predominantly North-South orientation of topography and narrowness between ridgelines. Spacing transects 800 m apart was intended to maximize observation efficiency and minimize obstructive effects of undulating terrain.

The flight crew chose to fly with rear cabin doors on. Experienced members of the flight crew noted that "doors on" reduced observer fatigue and increased safety. Cold and often wet winter conditions make it difficult to concentrate and add distractions that could lead to missing elk. Flying "doors on" increases safety by enhancing communication, i.e. no rotor turbulence in the mic, reducing cold weather and wind-related fatigue and eliminating the chance of loose objects flying out of the cabin and coming in contact with the rotor. While "doors on" is preferable in cold weather it may not be feasible in warmer weather. The large plastic doors amplify heat and onboard A/C and window vents may be insufficient to keep people cool. Even on mild temperature (18.3 degrees C) sunny days during this survey, it became warm in the cabin, caused nausea in some crew members and forced the pilot to set down. These events cause survey delays and should be mitigated by evaluating conditions choosing the strategy ("doors on" vs "doors off") that works best for crew comfort and safety.

Three methods were used to record elk group center points. The method that worked in the best interest of time and accuracy was to fly to the center of the elk group upon sighting and record a waypoint when the pilot said we were on target. This method worked well because counting and "comping" required us to fly close to the elk group. When elk moved/ran after initial sighting we noted the original sighting location, then flew back to this center point after we finished counting. When a center point was not able to be recorded due to safety or error using flight lines to estimate group center was a suitable method. In order to "comp" elk, we often flew a circle around them. Group center points were projected in the center of the circle after mapping the flight lines on Google Earth. Using rangefinders to calculate distance was problematic; this method should not be used. Rangefinders were not effective when "shooting" through the window and at ranges further that 250m when flying "doors off". They also required the pilot to hover on transect adding time to the survey, burning extra fuel, and allowing elk to move away from the initial sighted location. Obtaining the original elk location on a rangefinder is difficult due to a small field of view.

We will compare these distance sampling estimates with those obtained for portions of the study area by fecal DNA spatial capture-recapture in the Colusa-Lake Tule Elk Study 2017–2019 (Batter et al. 2020). Methods will also be compared fiscally in an attempt to determine a long-term monitoring strategy as laid out in the CDFW Elk Management Plan (CDFW 2018) and subsequent Monitoring Plans (in development).

Minimum count numbers across all four hunt zones declined from 2018 to 2019 but long-term minimum counts trends indicate an increasing trend over time (CDFW 2018). The yearly tag allotment is very conservative (<10% of min. counts) and accounts for a small percentage of the minimum populations in each zone and even a smaller percentage of the estimated population (Table 3). Each zone has opportunities to increase tag allotment and satisfy Goal 3 Objective 3.1 in CDFW 2018 but increased participation from private landowners, via SHARE or other, may be necessary to do so. In certain EMUs, hunting is limited to a small area where elk are available and increased pressure could modify elk behavior, hinder future hunts and increase depredation. We suggest a new Environmental Document increasing harvest based off population estimates that allows for an increase in tags up to 25% of the combined bull and cow population estimate. Most healthy deer and elk populations can withstand a 25% harvest of both sexes independently (Nelson and Hooper 1975). The suggested 25% limit of both sexes combined offers the potential to modestly increase harvest, but more importantly will allow for maximum flexibility in tag allocation (while maintaining a relatively conservative harvest rate), and afford the ability for CDFW to more dynamically manage elk populations, particularly as populations continue to increase, or should they experience rapid fluctuations. CDFW Elk Managers will continue to harvest elk at a rate that fits the goals and objectives as outlined in CDFW 2018.

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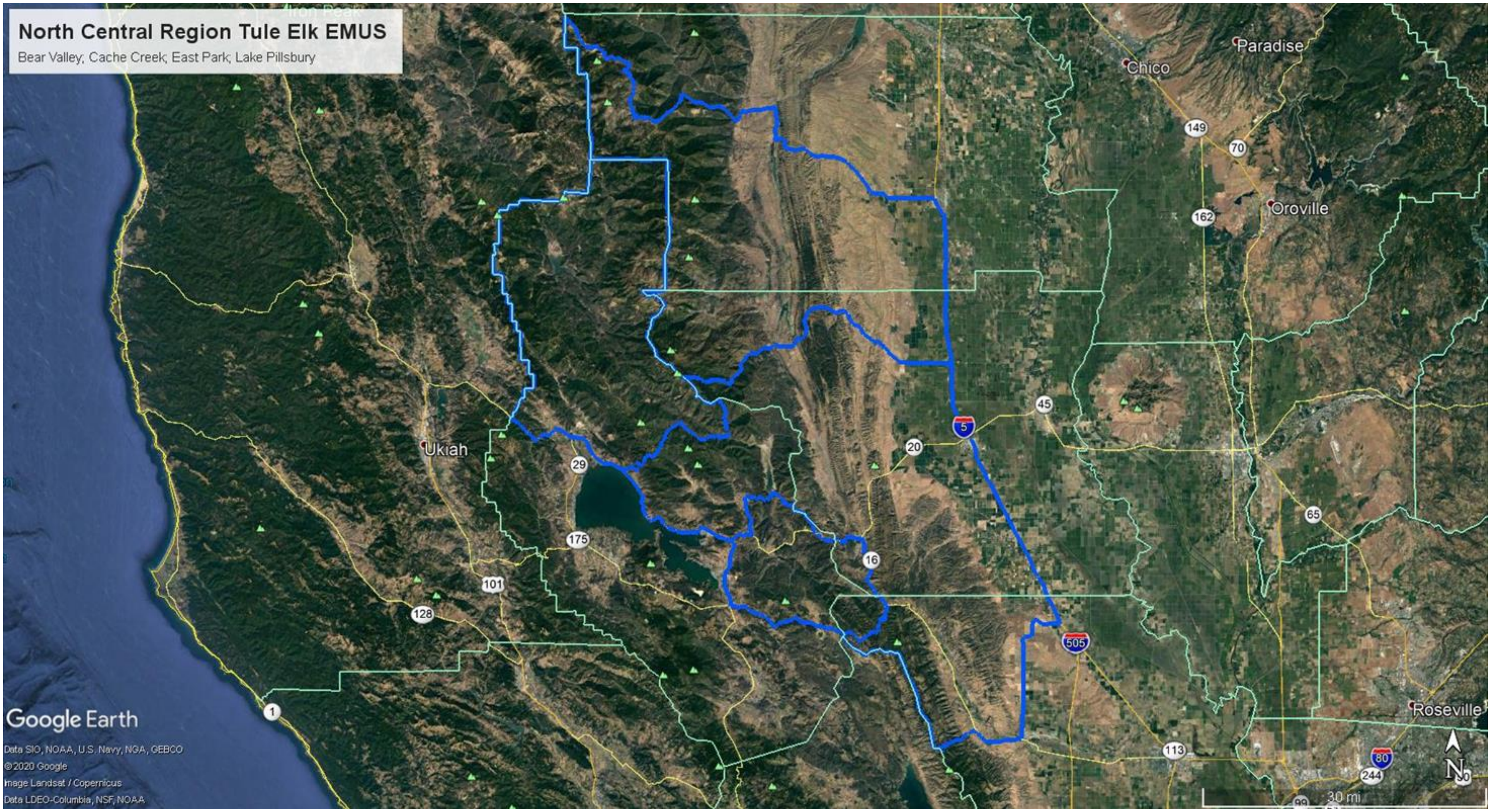

Figure 1. Boundaries of tule elk management units in North-Central California. The northernmost unit is East Park Reservoir, westernmost is Lake Pillsbury, southeastern is Bear Valley, and southwestern is Cache Creek.

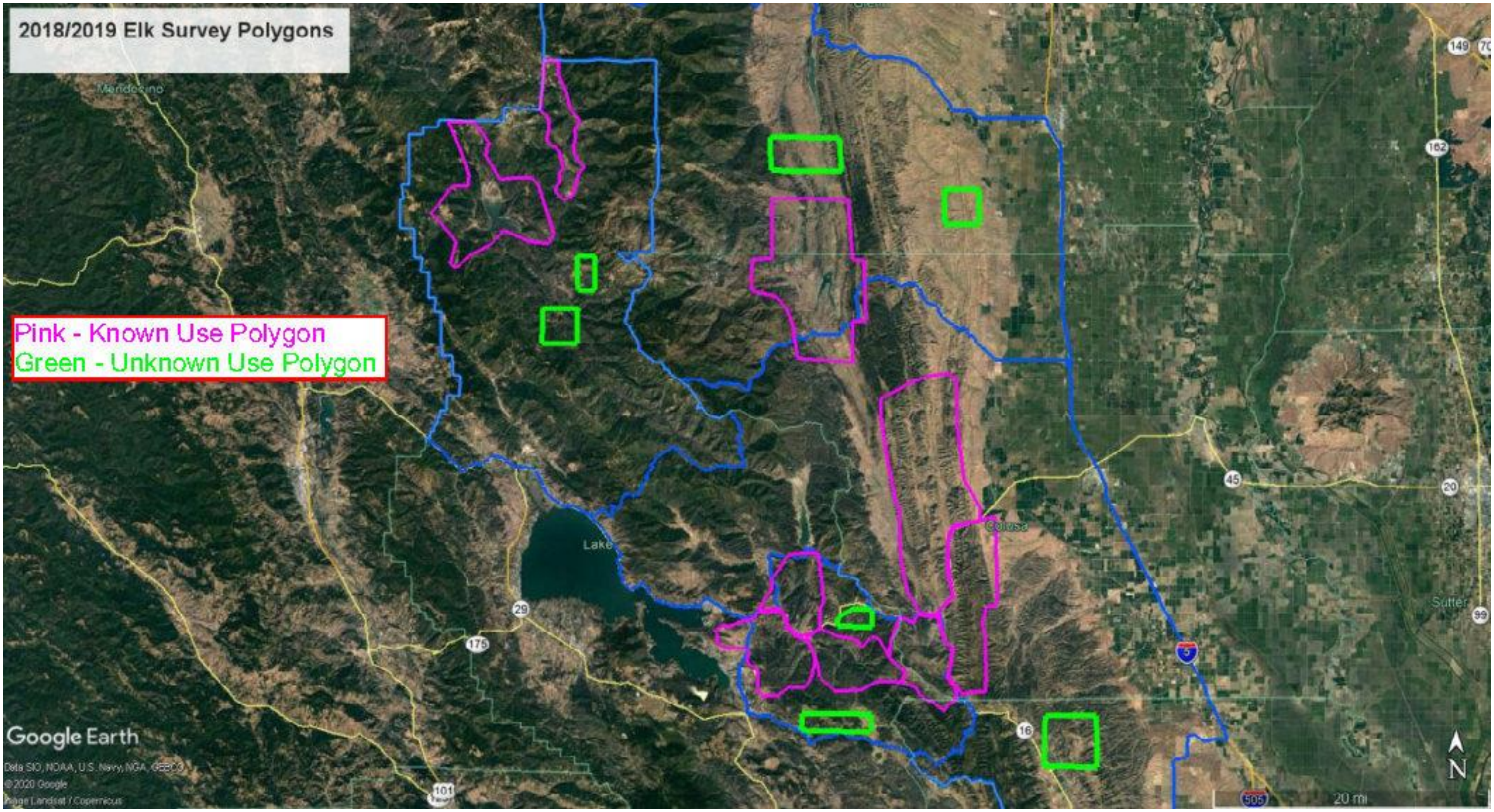

Figure 2. Elk survey polygons within the EMU boundaries.

Project:	Elk Zone:		Key
Date:			% Cover = Tree and shrubs at 10 meter radius, 10% increments
Start:	Observers		Distance = Check wypt -OR- Rangefinder, include Est (m) with rangefinder values
End:	FL:	FR:	Mat = Bulls with ≥ 5 antler points
Weather:	BL:	BR:	

Waypoint #	Time	Transect #	Bulls				Cows	Calfs	Uncl	Total	# Marks	Distance			% Cover	Comment
			Spike	Rag	Mat	Uncl						Wypt	Rangefinder	Est (m)		

Table 1. Number of elk groups and individuals detected by EMU and replicate in Colusa and Lake counties, CA, December 2018–19.

EMU	*Year (replicate)*	*Number of Groups*	*Bulls*	*Cows*	*Calves*	*Total*
Bear Valley	2018	28	66	143	25	244
	2019 (1)	20	36	110	28	174
	2019 (2)	21	44	135	36	215
Cache Creek	2018	18	36	75	17	128
	2019 (1)	9	25	58	8	91
	2019 (2)	11	29	46	10	85
East Park Reservoir	2018	8	45	49	14	108
	2019 (1)	8	35	40	8	82
	2019 (2)	5	35	38	8	81
Lake Pillsbury	2018	13	25	93	41	159
	2019 (1)	8	27	88	23	140
	2019 (2)	9	26	95	19	136

Table 2. Model-fitting and selection for detection probability of elk in Colusa and Lake counties, CA, December 2018-19. Detection models are named by covariates used to model detection scale parameter σ. Model COVER50 was dropped from multi-model inference because the covariate was collinear with COVER and the latter had more support.

Detection model	Parameters	AIC	Delta AIC	AIC weight	Pop Est
σ ~ COVER	2	709.6	0	0.803	675
σ ~ COVER50	2	712.8	3.2	-	677
σ ~ SIZE	2	714.1	4.5	0.081	608
σ ~ 1	1	714.5	4.9	0.070	696
σ ~ YEAR	2	715.3	5.7	0.046	715

Table 3. Covariate distance sampling population estimates for elk populations in Colusa and Lake counties, CA, December 2018–2019.

EMU	Count	Pop	SE	CIL90%	CIU90%	CV
Bear Valley	214	252	71	160	397	0.28
Cache Creek	108	144	61	74	281	0.42
East Park	95	109	45	56	210	0.42
Lake Pillsbury	149	166	62	91	302	0.38
Bear Valley + Cache Creek	322	396	94	270	581	0.24
Total	566	671	122	498	903	0.18

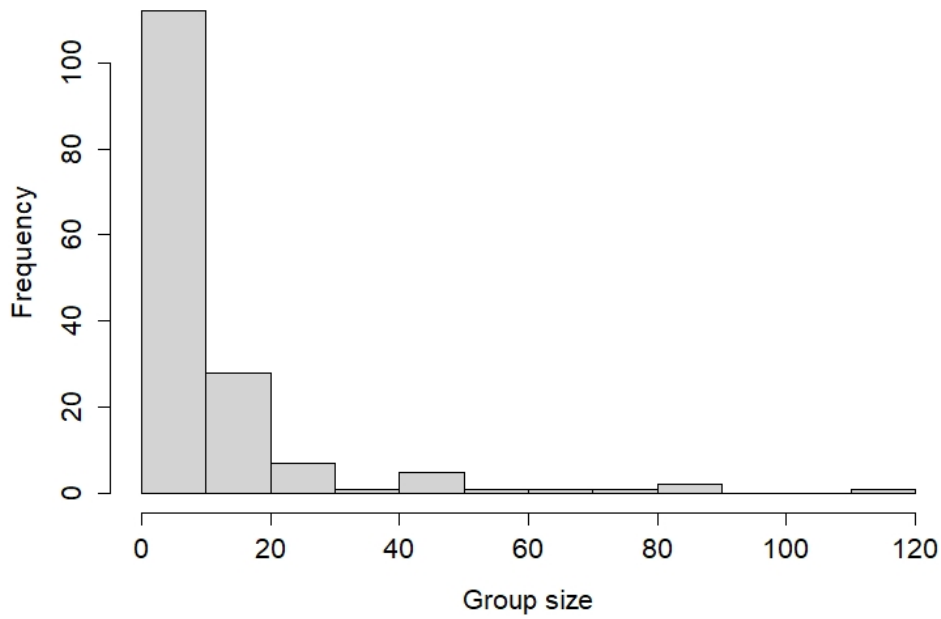

Figure 4. Histogram of group sizes in population survey of elk, Colusa and Lake Counties, CA, December 2018-2019.

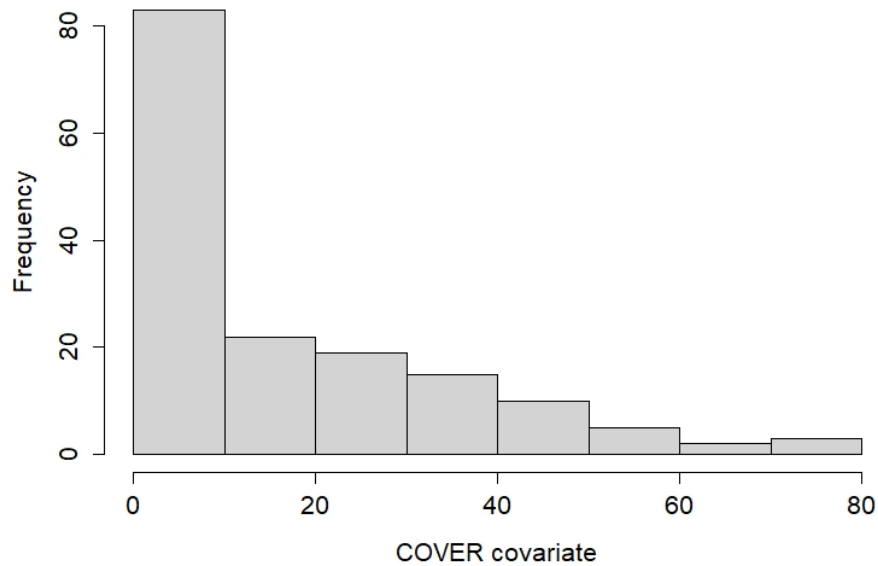

Figure 5. Histogram of percent cover at detected groups in population survey of elk, Colusa and Lake Counties, CA, December 2018-2019.

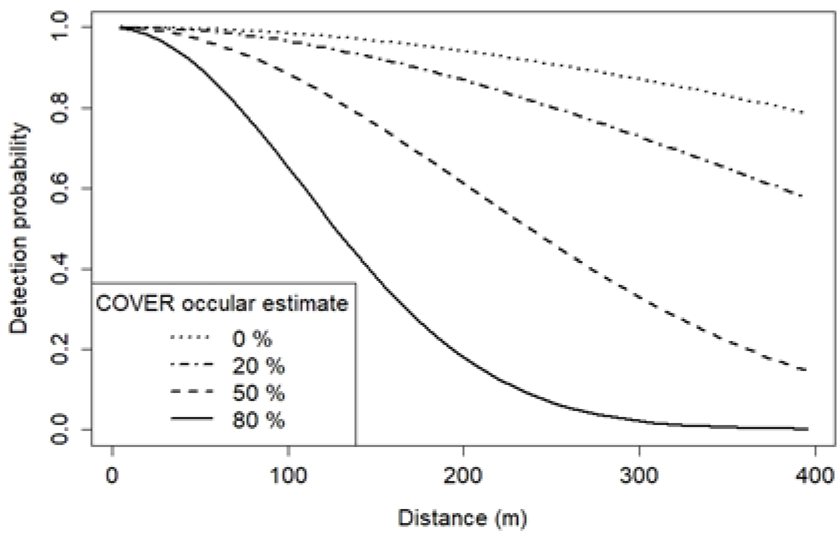

Figure 6. Interaction of distance and COVER covariate effects on detection probability of groups of elk in Colusa and Lake counties, CA, December 2018-2019.