Development and Assessment of an Aerial Survey Sightability Correction Model for Deer Management Units 500 and 510 (San Diego and Orange Counties)

Proposed Start and Completion Date

This proposal covers a three year period beginning 1 July 2017 and ending 30 June 2020.

Executive Summary

Estimating population parameters such as abundance and trend over time are essential for effective management of mule deer populations, especially where antlerless hunting is allowed. Helicopter survey of resident deer has been used as the primary technique to obtain population data for generating population estimates in the South Coast Region (SCR). This technique has proven effective, however sampling design, visibility bias, and incomplete detectability of deer have not been considered in previous surveys. Helicopter survey has thus not yielded data adequate to derive meaningful population estimates or measures of precision for surveyed deer herds.

A population monitoring program using helicopter plot (polygon) sampling adjusted for visibility bias (sightability) will be developed and used to obtain meaningful estimates of population abundance for resident deer in Deer Management Unit (DMU) 500 and 510 within the SCR. Use of this technique will provide sound data needed to derive robust population estimates and enable changes in population growth to be tracked over time. Aerial mark-resight population estimates will be used to validate initial population estimates derived from sightability correction.

Statement of Need

Well-designed monitoring strategies are vital to obtaining data required to adequately determine population parameters and produce robust deer population estimates. Explicit knowledge of population parameters are needed to effectively manage deer whether hunted or part of multi-species conservation planning programs. Population parameters of deer in DMU 500 and 510 are virtually unknown. This project will develop a statistically rigorous and repeatable population survey for resident deer within the Transverse and Peninsular Ranges Deer Conservation Unit (DCU), DMU 500 and 510 which allows reliable estimates of population abundance and density and rates of population change to be obtained over time.

Introduction

The California Department of Fish and Wildlife (CDFW) are entrusted with managing the State's diverse wildlife resources as well as the habitats upon which they depend. In part, the wildlife policy of the State is to provide beneficial use and enjoyment of wildlife by all citizens; maintain diversified recreational uses of wildlife, including sport hunting; provide for economic contributions to the citizens of the State through regulated management; and maintain sufficient populations of wildlife species and the habitat necessary to achieve the above-stated objectives (Fish and Game Code sections 1801-1802). Assuring that deer populations remain healthy and viable for future generations to observe and enjoy requires knowledge of the species' population size and trend. Gaining this knowledge is dependent on use of appropriate methods for tracking and forecasting changes in population size, sex and age ratios, and trend. Such knowledge for resident deer inhabiting DMU 500 and 510 are at best limited. Given public interest in deer issues such as hunting, land-use planning, habitat conservation, and human-deer conflict, management actions taken must be based on accurate and up-to date population data. The SCR has strived over the last decade to adequately monitor deer populations within its jurisdiction. However, lack of attention to sampling design and visibility bias along with limited funding have resulted in insufficient data needed to establish meaningful population estimates and track population trends.

Vegetation structure, topographic relief, and deer density in DMU 500 and 510 are diverse. Topography can vary drastically in short distances as can vegetation structure, making sampling deer difficult. Deer in these DMU's inhabit mixed-chaparral woodland, chamise chaparral, oak woodland, coniferous forest, juniper woodland, riparian woodland, desert scrub, sage scrub, grassland, and numerous other habitat types. Estimating population size is one of the most difficult and expensive aspects of deer management especially when confronted with diverse vegetation structure and topography. Thus, the techniques and strategies selected to monitor population parameters must be appropriate for the survey conditions and data needed but also cost effective and efficient over time. Monitoring techniques must be statistically sound and designed to provide quality data necessary to make informed deer management and conservation decisions.

Determining the most appropriate survey technique or techniques for individual DMU's is critical for reliability, repeatability, and the utilization of limited resources. Numerous techniques are used to monitor the status, composition, and trends of mule deer populations throughout their range. These methods range from trend indices, which provide information on whether a population is increasing, stable, or declining, to abundance estimators, which provide a population estimate (Lancia et al., 1996). Common trend indices include minimum counts, spotlight counts, road counts, and pellet group surveys. Most trend indices however, have assumptions that usually result in trend information of uncertain value, and very few have been calibrated to actual population size (Keegan et al., 2011). Population estimates are preferable to trend estimators because they allow direct calculation of abundance, provide measures of precision (confidence intervals), and can be converted to densities. Sample-based abundance and density techniques offer the most statistically meaningful methods to monitor population parameters. Common abundance and density techniques include distance sampling, plot sampling, plot sampling with sightability models, and mark-resight. Sightability models developed in conjunction with aerial surveys in defined sampling units (polygons) is an effective and widely used technique to derive population estimates (Samuel et al., 1987; Otten et al., 1993). Sightability models can be expensive to develop because they require use of a helicopter and marking animals. However, subsequent correction of survey data with the use of a sightability model eliminates the need for maintaining marked animals, thereby allowing more extensive sampling of their range and reduced survey costs. Development of a sightability model also allows more accurate estimation of buck:doe ratios (Samuel et al. 1992, McCorquodale 2001) and long-term collection of robust data needed to derive population estimates.

In the SCR, deer population size has historically been derived from uncorrected data obtained from quadrat and line-transect helicopter surveys. Data collected from aerial surveys can underestimate population size and result in low precision due to visibility bias and inefficient sampling design (Caughley 1974, Steinhorst and Samuel 1989). During aerial surveys, it is rare that all animals are sighted by observers and, in fact, many animals are not observed. For example, only 17% of marked animals were observed during surveys of elk (Lovaas et al. 1966), and only 7-19% of radio-collared mule deer were observed in two previous surveys using distance sampling in eastern San Diego County (R. Botta, unpublished data). Aerial plot sampling with visibility correction offers an effective and efficient method to estimate population size and trend over large areas and in many habitat types found in DMU 500 and 510. Aerial mark-resight population estimates can be used to validate initial population estimates derived from sightability model development.

Objectives

The objectives of this proposal are:

1. Create a sightability model that is robust to DMU 500 and 510 habitat and survey variables and is simple enough to understand and apply to aerial survey results.
2. Use aerial mark-resight sampling to validate aerial sightability estimates.
3. Implement standardized population monitoring in DMU 500 and 510 which produce reliable estimates of population size and density and allows population trend to be tracked over time.

Study Area

The project area is located in the Peninsular Mountains within the Transverse and Peninsular Mountain Ranges DCU in southwestern California (Figure 1). The Peninsular Ranges are a series of smaller north-south oriented mountain ranges stretching 1,500 km from Orange County in southern California to the tip of Baja California Mexico. Specifically, the project area encompasses the Santa Ana Mountains of eastern Orange County (DMU 500) and portions of northern, central, and southern San Diego County (DMU 510). Project areas in San Diego County from north to south include Oak Grove Valley, San Felipe Valley, Cuyamaca Mountains, Jamul Mountains, and San Ysidro Mountains.

The Santa Ana Mountains cover an area of 5,450 km^2 much of which is within the Trabuco Ranger District of the Cleveland National Forest. The privately owned Irvine Ranch and Rancho Mission Viejo cover approximately 469 km^2 in the central portion of the mountain range. Roughly 291 km^2 of these privately owned lands are in dedicated conservation. Elevations range from 152 meters near the Santa Rosa Plateau to 1,734 meters at Santiago Peak. Vegetation types include grassland, coastal scrub, buckwheat scrub, chaparral, mixed oak woodland, coast live oak woodland, and montane coniferous forest.

In San Diego County, the areas listed are predominately administered by the CDFW, California Department of Parks and Recreation (CDPR), Bureau of Land Management (BLM), and U.S. Forest Service (USFS). Numerous privately-owned ranches and small rural properties are found throughout these areas and in many cases create in-holdings within the public owned lands. Elevations range from 152 meters in the Jamul Valley near the U.S. - Mexico border to 1,691 meters at Beauty Mountain near the Oak Grove Valley. Vegetation types include grassland, coastal and upland sage scrub, buckwheat scrub, riparian woodland, coast live oak woodland, juniper woodland, mesquite woodland, chamise chaparral, red-shank chaparral, mixed chaparral, desert transition chaparral, cottonwood-willow riparian forest, mixed hardwood-coniferous forest, mixed evergreen forest, and montane coniferous forest.

Methods

Helicopter Capture

Capture and radiocollaring of deer have been successfully undertaken in DAU 500 and 510 using helicopter net-gun, drive-net, and free-range darting. Up to 35 adult deer will be captured, sampled and fitted with radiocollars in each of 3 sampling polygons during the winter and/or spring of 2017. Replacement of collars lost through mortality or malfunction the first year will be carried out as needed in each of the sampling polygons during winter and/or spring of 2018 and 2019. Deer will be captured primarily via helicopter net-gun (Jessup et al. 1988). Other capture methods such as drive-net, drop-net, and chemical darting may also be employed if helicopter net-gun proves infeasible. Use of a helicopter will allow selective capture of deer which is an essential element of the project. To assure the health of captured deer safety and medical considerations listed in the CDFW Wildlife Investigations Laboratory's Wildlife Restraint Handbook will be followed.

For this project, it is anticipated that seven days of capture time will be needed during the first year and up to 3 days of capture time in years two and three. VHF beacon and GPS location fix scheduling will be programmed such that battery life of the collars will be sufficient for the duration of the study. Previously fitted collars recovered from mortalities will be refurbished and deployed on new deer to replace those lost. Fixed-wing flights to monitor deer for mortality and general location during the life of the project will be undertaken twice monthly using CDFW Air Services. Flights will occur after each capture operation to assist in determining if any capture related mortalities occurred.

Deer will be selected for capture to meet the following goals:

- Deer will be dispersed across each of the 3 polygons. To increase dispersion across each polygon, deer collared will be selected randomly and no more than two deer per group encountered will be captured.
- Deer captured will be dispersed across all vegetation categories in each of the 3 sampling polygons.
- Males and females will be represented equally in the sample because gender-specific differences may exist in the probability of detection during surveys due to differences in habitat use, group size, or activity (McCorquodale 2001, Rubin and Bleich 2005). However, skewed sex ratios in the population may preclude this and result in the collaring of males and females in proportion to their availability.

GPS Radiocollars

Deployment of GPS radiocollars and marking deer such that each is individually identifiable (using color coded radiocollars and ear tag in varying combinations) will be integrated into sightability model development. Use of GPS along with the number of collars to be deployed will provide detailed information on deer movement and location during surveys and provide for a large sample size. GPS location fixes will be recorded every 5 minutes from 0600 to 1100 hours and from 1500 to 1900 hours during periods of aerial survey. During non-survey periods locations fixes will be recorded every five hours. Employing GPS technology and remote sensing will provide accurate location, movement, and habitat use data which is essential given the potential for collared deer to move long distances in the time between the survey and collection of data on missed deer. Unlike VHF, GPS technology will allow accurate location and activity data to be collected as surveys are flown. Use of GPS collars can eliminate the bias associated with returning hours later to obtain data for missed groups and the extra flight costs involved in searching for missed deer groups. Additionally, collared deer will be used to relate the detectability of marked deer to survey variables such as vegetation and terrain class, deer group size, helicopter type, and observer experience.

Aerial Sightability Model Development:

Development of a sightability model will be based on empirical data from trials conducted in the field. Model development will involve use of a helicopter to survey multiple 30 km^2 sampling plots (determined once deer are radiocollared) within larger sampling polygons in DMU 500 (Figure 2) and 510 (Figure 3). The sampling plots are representative of the major habitat types and topography found throughout the DMU's and to be encountered during future aerial surveys. Sampling plots will be surveyed at 100% coverage in 1.5 to 2.0 hours allowing each deer in the survey area the opportunity to be seen (Cogan and Diefenbach 1998). During survey pertinent data will be collected on observed marked deer and their associated groups. Immediately after the survey, marked deer that were missed during the survey will be located and the same data will be collected. Polygon boundaries were previously established using physical features such as drainages, ridgetops and roads for ease of identification and re-survey (Samuel et al. 1987, Freddy et al. 2004). Sampling plots boundaries will be mapped in GIS and used to guide the helicopter during surveys.

Vegetation communities in the CalVeg-zone 7 classification system have been grouped into four dominant vegetation (cover) types: open, low brush, mixed brush, and forest to facilitate model development. Additionally, terrain has been classified as flat, rolling, rough, or rugged. Flat terrain is considered to have < 5% slope, rolling terrain 5-30% slope, rough terrain 30-60% slope, and rugged terrain greater than 60% slope.

The sightability model will be developed using logistic regression methods to account for undetected deer based on a variety of sightability covariates specific to survey of DMU 500 and 510 (such as aircraft type, deer group size, percent vegetation cover, and observer experience).

Deer groups "seen" or "missed" will be treated as a binary dependent variable in the analysis and development of the model. Independent variables which will be recorded for each group will include the following, whether seen or missed:

- Group size
- Group composition (Male, Female, Yearling, Fawn)
- Activity (Bedded, Standing, Moving)
- Vegetation category (Open, Low brush, Mixed brush, Forest).
- Percent vegetation cover within a 10 meter perimeter of the group.
- Topography (Flat, Rolling, Rough, Rugged). Alternatively, a quantitative measure of slope and ruggedness, estimated via GIS, may be used.
- Ambient temperature
- Wind speed
- Time
- Light intensity (Flat or Bright)
- Observer experience
- Observer fatigue

All influencing factors which can be controlled, such as flight speed, flight altitude, primary recorder and observer, number of observers, pilot, and aircraft will be standardized.

Aerial Mark-Resight Survey:

Mark-resight sampling will be used to obtain an alternate estimate of population abundance during sightability model development. This technique requires individually marking a sample of deer in an area with color-coded radiocollars and ear tags and flying surveys over those deer to obtain an estimate of population abundance based on the proportion of marked deer observed. Mark-resight is a variation of the mark-recapture technique (Seber 1982) and is generally considered one of the most reliable methods for estimating population abundance. However, this technique can require that a large number of marked animals be present in every sampling unit each time a survey is conducted. This can be cost prohibitive and unrealistic for long-term population monitoring. For this reason mark-resight is not a feasible technique for long-term use in DMU 500 and 510.

Although mark-resight survey requires large numbers of marked animals on the survey area every time a survey is conducted, use with sightability models only requires marked animals during model development (Anderson and Lindzey 1996). Mark-resight estimation will be used in the development of a sightability correction model to validate estimates derived from the sightability correction model. To facilitate mark-resight estimation up to 35 adult deer in each of 3 sampling polygons will be radiocollared (marked) during the first year of the project. Replacement of radiocollars lost due to mortality or malfunction will be required during year two and three of the project. GPS radiocollars will be used over the course of the project in order to obtain locations and gather information on deer not seen during surveys. This will allow accurate location and activity data to be collected as surveys are flown and eliminate the bias associated with returning after completion of surveys to obtain data for missed groups.

Data Analysis

For development and analysis of the sightability model, deer groups "seen" or "missed" in the sampling plots will be treated as a binary response variable (Samuel et al. 1987), while independent variables (covariates) that will be used to predict the probability of detecting a group will include group characteristics listed above such as group size, composition, activity, vegetation type, and percent vegetation cover.

We will use univariate analyses such as chi-square contingency tests to examine the influence of single covariates on sightability (Sokal and Rohlf 1995, Anderson et al. 1998). For continuous variables, we will transform non-linear relationships prior to multivariate analyses. We will then use multivariate logistic regression (Sokal and Rohlf 1995) to examine the influence of group characteristics on sightability and to develop a sightability model (Steinhorst and Samuel 1989). Samuel et al. (1987) noted that although past studies have used univariate analysis to examine factors influencing visibility, that approach could overestimate the number of factors influencing sightability due to serial correlation among a number of factors, even when only a subset are important. For example, Samuel et al. (1987) found that the significant effect of animal behavior disappeared when group size and vegetation cover were included in the model, suggesting that they may have been correlated. Thus, we will develop a single a-priori set of models with various covariates, covariate groupings, and functions (quadratic, additive, and/or interactive (i.e., multiplicative)) that can be compared as a single model set with Akaike's Information Criterion (AIC) to select a "best approximating model" (Burnham and Anderson 2002). We will explore use of our "best" model as the foundation for developing a southern California Aerial Survey Program in Visual Basic or the R statistical software package.

Data collected during full surveys of the three sampling polygons will be used to generate population estimates using the following two methods: (1) application of the sightability model to groups observed during the survey, and (2) abundance estimation using marked deer with the mark-resight technique. Resulting estimates and their confidence intervals will be compared to evaluate the sightability model and its use in future surveys of DMU 500 and 510.

Products (and estimated dates of completion)

A sightability model which accounts for visibility bias encountered during helicopter quadrat sampling will be developed.

Annual progress reports will be submitted yearly on June 30. A final report will be submitted within three months of project completion. These reports will contain data summaries, budget expenditure, and will address project impediments and other issues. Data will be delivered to the Wildlife Branch annually or as requested and contain the following:

- Data including maps showing capture/survey areas and locations of individuals
- Results (population size estimates and confidence intervals).
- Conclusions regarding feasibility of regular monitoring, sample size and efforts required, power analyses related to trend detection, protocols for regular monitoring.
- Estimated costs for regular population abundance estimates.
- Publication of results in peer reviewed journal.

A graduate student from San Diego State University will prepare for publication a manuscript describing the development and use of aerial population estimation techniques with visibility bias correction in southern California deer herds.

Collaborators

- CDFW (Project Lead): Randy Botta, South Coast Region
- CDFW (Field Lead): Janene Colby, South Coast Region

Other Collaborators

- San Diego State University - Dr. Megan Jennings and Dr. Rebecca Lewison
- CA Department of Parks and Recreation - Dr. Jeff Manning
- Cleveland National Forest - Jeff Wells
- BLM - Camden Bruner

Program Planning

The project lead will be in regular contact with CDFW Deer Program staff in order to discuss, review and evaluate project progress. Additionally, resulting population data will be provided during each field season. Further, the project lead will meet with collaborators quarterly, or more often as needed, in order to address any issues and to keep the project on track.

Other Resources requested from CDFW.

None anticipated.

Issues to be Resolved

- FY 2017-18 Federal Wildlife Restoration Grant Approval
- CDFW LMAC Proposal Approval
- Develop Final Project Activity Schedule Upon LMAC and WRA Grant Approvals
- San Diego State University Contracting
- Telemetry Equipment (GPS Collar) Purchase
- Helicopter Capture and Survey Scheduling Finalization
- Final Agency Approvals to Conduct Work on Federal and State Lands
- Capture Plan Development and Administrative Approval

Personnel Requirements and commitments from CDFW

Project Lead is Mr. Randy Botta (CDFW) and he will oversee data management, project timeframes, helicopter requirements and scheduling, collar management (specifications and ordering), and overall project coordination. Ms. Janene Colby (CDFW) will oversee day-to-day field activities, including ground and fixed-wing telemetry monitoring, supervising temp help, and investigating mortalities. Ms. Katie Filippini (CDFW) will assist with telemetry monitoring and field sampling. The 3 above will spend 15% of their time each month except in December and January, when they will spend more than 50% of their time conducting surveys and captures. Dr. Megan Jennings, Assistant Adjunct Professor, San Diego State University (SDSU), will provide assistance with study design, data analyses and along with Dr. Rebecca Lewison will oversee a graduate student and field technicians as part of a contract funded through an existing SCR federal Wildlife Restoration Act (WRA) grant. All CDFW project personnel will assist on captures and surveys. SDSU project staff may assist with captures and along with CDFW project staff will be involved in developing the progress reports and publications that come from this project. WIL staff will be needed during the capture and collaring of deer.

Budget Detail

Table1. Proposed Budget Summary

Item Description	Year 1 FY2017/2018	Year 2 FY2018/2019	Year 3 FY2019/2020
SDSU Contract (WRA Grant)	12 months @ $45,000	12 months @ $45,000	12 months @ $45,000
Temporary Help (WRA Grant)	12 months @ $12,000	12 months @ $12,000	12 months @ $12,000
GPS Satellite Radiocollars (BGFA)	100 Collars @ $1,800 each = $180,000 July-August 2017	30 Collar Refurbishment @ $1,000 each = $30,000 July-August 2018	20 Collar Refurbishment @ $1,000 each = $20,000 July-August 2019
Helicopter Capture (BGFA)	70 does & 30 bucks $2,100/hour @ 49 hours = $102,900 February 2018	20 does & 10 bucks $2,100/hour @ 21 hours = $44,100 February 2019	10 does & 10 bucks $2,100/hour @ 14 hours = $29,400 February 2020
Ground Capture Support (WRA Grant)	$1,000 January-March 2018	$1,000 January-March 2019	$1,000 January-March 2019
Helicopter Survey (BGFA)	$1,700/hour @ 35 hours = $59,500 December 2017	$1,700/hour @ 35 hours = $59,500 December 2018	$1,700/hour @ 35 hours = $59,500 December 2019
CDFW Air Services Fixed-Wing Flights (SCR O&E)	$113/hour @ 144 hours/year = $16,272	$113/hour @ 144 hours/year = $16,272	$113/hour @ 144 hours/year = $16,272
Total Estimated Annual Project Cost	**$416,672**	**$207,872**	**$183,172**
Total Estimated Funds Requested	**$342,400**	**$133,600**	**$108,900**
Total Project Cost: $807,716			
Total Requested Cost: $584,900			

References

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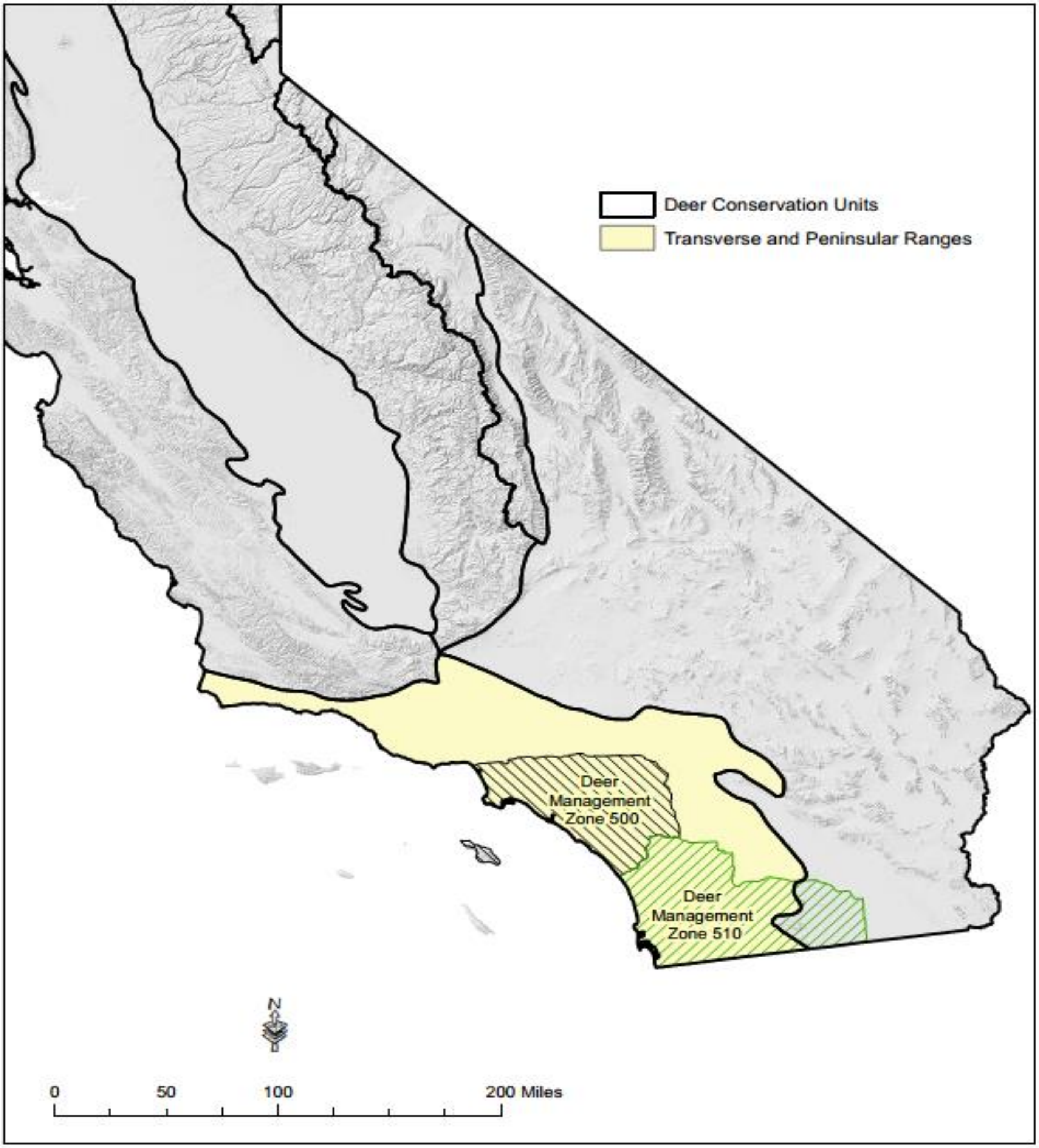
Figure 1. Project Location



2017 Deer Survey
Ken Devore R5 GIS

Transverse and Peninsular Ranges
Deer Conservation Unit & Deer Assessment Units 500 and 510

Figure 2. DMU 500 Sampling Polygons

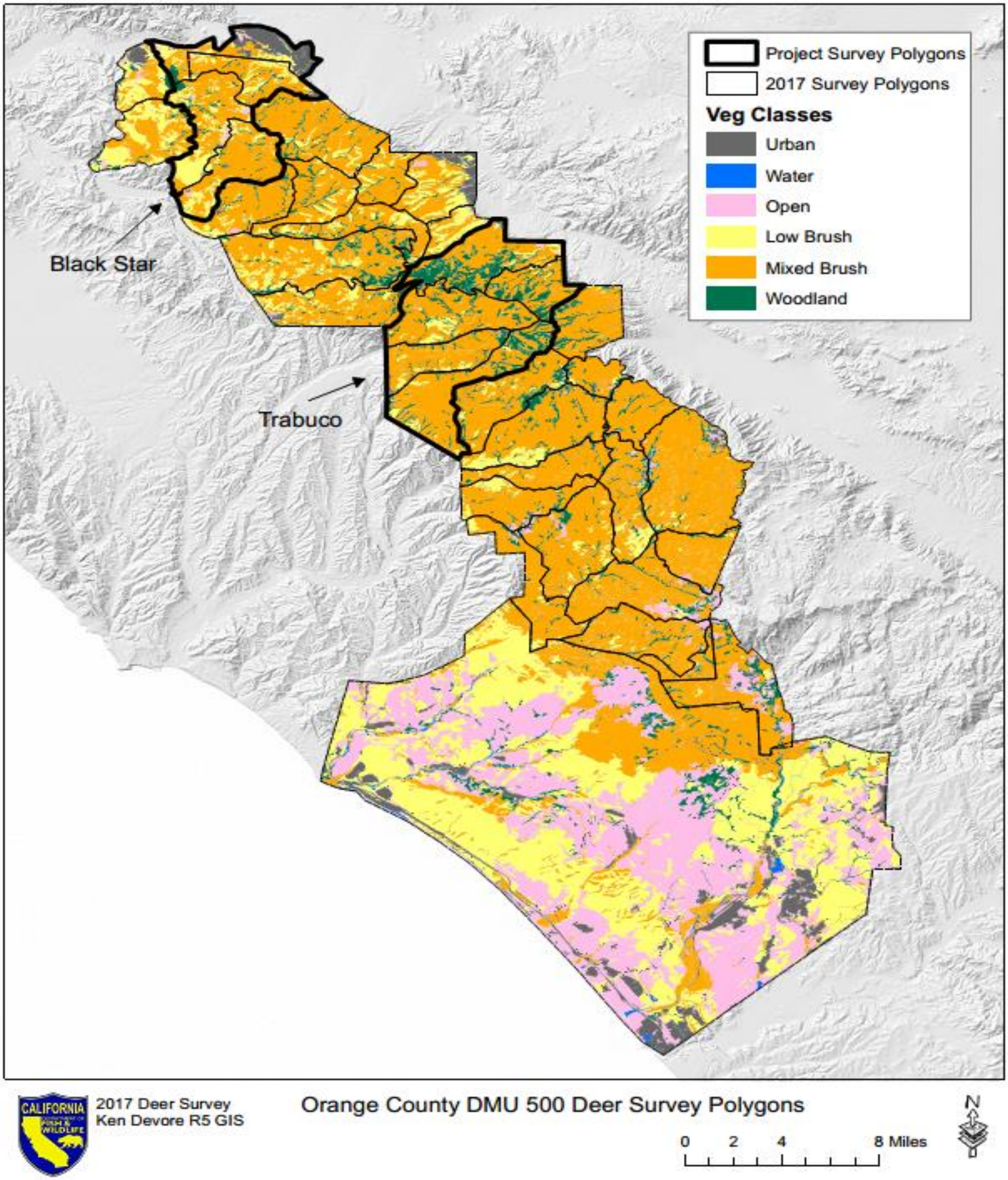


Figure 3. DMU 510 Sampling Polygons