Survival of pronghorn fawns on the Carrizo Plain National Monument, California: relationships between offspring recruitment, habitat, and population density.
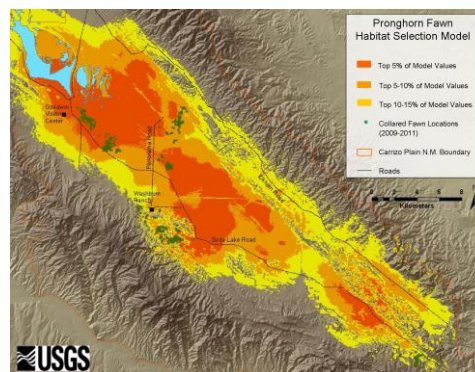
Administrative Report
25 November 2013

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Report Prepared for:
Carrizo Plain National Monument
Bureau of Land Management
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Executive Summary
Recovery of highly reduced pronghorn (*Antilocapra americana*) populations can be limited by offspring recruitment, the number of young that survive to sexual maturity. Low recruitment in pronghorn is commonly associated with high predation, poor habitat conditions and inclement weather. Relatively less understood are the effects of population density on recruitment. Low density pronghorn populations may experience an Allee effect in which population growth rates decline with reduced numbers of conspecifics. The Allee effect significantly increases the risk of localized extinction and is an important consideration for management of declining pronghorn populations.

On the Carrizo Plain National Monument (CPNM) in southwestern California, a translocated population of pronghorn has experienced a significant reduction in numbers over twenty years. Causes of population decline for pronghorn on the CPNM are not well understood and, prior to this study, a paucity of information has been available for offspring recruitment. Quantifying recruitment and evaluating the relationship between fawn survival and the factors that affect it are critical for understanding population dynamics of pronghorn on the CPNM. The primary objectives of this study were to quantify survival of pronghorn fawns on the CPNM, test for conditions that might produce an Allee effect by examining the relationship between fawn survival, predation, and birth synchrony, and to evaluate the relationship between fawn survival and habitat characteristics, weather, diet, and forage conditions.

Forty five fawns were born on the CPNM during 2009-2011. We equipped 20 of these fawns (44% of the total number born) with GPS/VHF expandable, breakaway collars and monitored their survival until they were > 90 days of age. Of the 45 fawns born, 12 survived; of the 20 fawns we collared, four survived. Survival of collared fawns (20%, n = 20) and uncollared fawns (32%, n = 25) did not differ (z = -0.25, p = 0.81), nor did survival between male and female collared fawns (z = -0.32, p = 0.75). Annual fawn productivity and survival varied across years (mean productivity = 15.0 fawns, SE = 3.5 fawns and mean survival = 30.7%, SE = 8.5%). Fawn survival on the CPNM was similar to that found for other pronghorn populations across the species' range (29.4%, n = 995; z = 0.22, p = 0.82). Results for the Kaplan-Meier (K-M) survival curve indicated that 50% of fawn mortality occurred prior to 20 days of age and that the greatest rate of mortality took place between 16 and 18 days. K-M survival curves did not differ between years. Causes of mortality included predation (28.6%; n = 6), health-related issues (0.1%; n = 2) and undetermined causes (61.9%; n = 13). For the six predator related mortalities, we detected predation by coyote (n = 6) and golden eagle (n = 1). Results from laboratory necropsies performed for the two health-related mortalities indicate that death was caused by an infected umbilical cord for one individual and a lacerated liver (possibly from being stepped on by its mother) for the other.

Births for all three years occurred between April 25 and May 25. Date range and synchronicity of fawn birth distributions was variable between the three years. Mean range in which births took place was 22.7 days (SE = 6.4 days). Birth synchrony was detected for 2009 and 2010, where peak offspring productivity occurred during the first two quarters of each year's perspective birth distribution (before quartile 1 and between quartile 1 and 2). Birth synchrony was not detected for 2011, where peak periods of offspring productivity occurred at the beginning (before quartile

1) and at the end (after quartile 3) of the birth distribution. All 12 surviving fawns in the study were born during peak periods and none were born during non-peak periods. Survival was not related to overall offspring production across the three years ($\chi^2 = 6.00$, df = 4, p = 0.20).

To test for Allee effects, we investigated the density dependent feedback of population size on logarithmic per capita population growth rate. Population size for the CPNM and CV herds were estimated using winter count totals from aerial surveys conducted by the CDFG from 2000 to 2011. Patterns of pronghorn abundance and distribution appeared consistent between ground and aerial surveys conducted during the fawning seasons from 2009 to 2011. From 2000 to 2011, we found a significant negative relationship between population size and per capita population growth rate for pronghorn across the entire Carrizo Plain (i.e., CPNM and CV herds combined), F = 5.93 , df = 1, Adj R^2 = 0.33 ,p = 0.04). Independently, however, this relationship was only significant for the CV herd (F = 21.70, df = 1, Adj R^2 = 0.67, p = 0.001).

We used binary logistic regression within an information-theoretic approach to assess factors influencing fawn habitat selection and survival. Two candidate models showed substantial support as the best approximating models for fawn habitat selection ($\Delta AIC_c < 2$). Model 1 showed that fawn locations were positively associated with increased forb composition and fawn visibility (proportion of a 1 meter measuring stick visible at fawn height; 0.5 m) at 100 m distance, and negatively associated with increased vegetation height at 5m, fawn visibility at 5 m and 50 m, slope of terrain, and linear distance to saltbush and water. Model 2, consisted of the same parameters and respective positive/negative associations as Model 1, excluding forb composition at fawn locations and fawn visibility at 50 m. The fawn survival model compared the relationship between locations of fawns ≤ or > 17 days of age (dichotomous response/dependent variable) and the same spatially explicit, landscape scale macrohabitat features used in the fawn habitat survival model (explanatory/independent variables). There were two best approximating models. Model 1 indicated that locations of individuals which lived greater than 17 days were positively associated with increased slope and distance to main roads (i.e., Soda Lake Rd, Selby Rd, Panorama Rd, and Elkhorn Rd.), and negatively associated with increased linear distance to water, fences, and all roads. In addition to the same parameters and respective positive/negative associations as Model 1, Model 2 (global model) showed a negative association with linear distance to saltbush. Locations of both collared and uncollared fawns were dispersed throughout the CPNM; located on both the north and south ends of the plain, as well as on the east and west sides of the plain. Locations of both collared and uncollared fawns were dispersed throughout the CPNM; located on both the north and south ends of the plain, as well as on the east and west sides of the plain.

Pronghorn diets were estimated using micro-histological identification of plant epidermal fragments in fecal material. Annual diet composition consisted of 76.19% (1.83% SE) forbs, 14.58% (0.95% SE) grasses, 6.10% (0.98% SE) shrubs, and 3.13% (0.26% SE) other forage items (seeds, lichens and unidentified flowers). Pronghorn consumed more than 50 different individual forage items. At least 42 different plant taxa were identified in the diet, including 26 species of forbs, 9 species of grasses and 8 species of shrubs. Principle forage items comprised ≥ 5% of the dietary composition for any one season. Principle forage items among forbs included *Astragalus* spp., *Camissonia* spp., *Erodium* spp., *Lotus* spp., Aster family flower, Borage family, and legume pod; among grasses were *Avena* spp. and *Bromus* spp.; and for shrubs was *Atriplex*

spp. Among principle forage items, *Erodium* spp. comprised >20% of the diet for all seasons; and *Astragalus* spp., Aster family flower, and *Atriplex* spp. represented ≥ 10% of the dietary composition for at least one season. In comparison to pronghorn occupying grassland, shrubsteppe and desert biomes, pronghorn on the CPNM appeared to have consumed a comparable amount of grasses, but a greater percent of forbs and a fewer percent of shrubs.

Plant biomass and forage availability (forb, grass, shrub) within the CPNM was measured along 23, 50-meter random transects during spring, summer and winter 2008-2011. Plant composition of above-ground annual vegetation was collected within ten 0.5 meter plots evenly distributed along each transect. Annual composition of forage available for pronghorn consumption consisted of 35.46% (16.43% SE) forbs and 64.54% (16.43% SE) grasses. Shrubs were not detected within vegetation transects. Forb and grass cover were representative of high quality grassland-scrub habitat. Shrubs however, were scarce and undetected within our vegetation transects; and shrub cover was indicative of low quality grassland-scrub habitat.

Monthly fecal nitrogen (FN) values were highest in March 2009 (3.06%) and April 2008 (3.09%) and lowest during January 2008 (2.01%), January 2009 (2.33%) and August 2009 (2.29%). Monthly fecal diaminopimelic acid (FDAPA) values ranged from a high of 1.15 mg/g during March 2009 to a low of 0.27 mg/g during January of 2008.

Results from this study indicate that, under current biotic and abiotic conditions on the CPNM, increased pronghorn population density may not occur without management strategies which enhance fawn productivity and survival. Additional translocations of adult pronghorn may augment population size temporarily by promoting birth synchrony and decreasing potential Allee effects, as well as by reducing the overall risk associated with environmental and demographic stochasticity. However, habitat conditions within the CPNM indicate low carrying capacity for pronghorn and future translocations are not likely to succeed without prior rangeland manipulation.

Introduction

Pronghorn (*Antilocapra americana*) were once abundant and widely distributed throughout many regions of California. Historically, the Central Valley contained one of the highest pronghorn densities in the country (Pyshora 1977, Yoakum 2004a). The species occupied habitat from the northeastern part of the state, throughout the Sacramento and San Joaquin valleys, and along both sides of the coastal range (Bryant 1848, Fremont 1849, Newberry 1855, Baird 1857). Numbers began to decline during the second half of the 19th century due to rapid habitat loss associated with agricultural development and overhunting (Yoakum 2004a). By the 1930's pronghorn were regionally extinct in all areas of California except the northeast (McLean 1944, Yoakum 2004a) and presently are absent from an estimated 70% of their historic range (Yoakum and Koch, 2009).

Declining or locally extinct pronghorn populations are often augmented through the translocation of conspecifics from regions of high productivity, a management practice which has been remarkably successful across North America (O'Gara, et al. 2004). The California Department of Fish and Game (CDFG) conducted numerous translocations of individuals from northeast California to southern regions of the state. Perhaps the most ambitious of these reintroduction efforts has taken place on the Carrizo Plain, where 240 pronghorn were released during a series of translocations in 1987, 1988 and 1990 (Sommer 2012). Information from over ten years of aerial surveys indicates that post-release numbers on the Carrizo Plain have fallen by nearly 70% (Sommer 2012). The distribution of pronghorn on the plain consists of two distinct herds (i.e., groups). The California Valley (CV) herd, composed of approximately 50 individuals, occupies mostly private property along the northern end of the plain. The Carrizo Plain National Monument (CPNM) herd, consisting of 20-30 individuals, is found within federally protected lands along the southern end of the plain. Although some degree of interchange between herds is expected to occur, significant immigration and/or emigration is considered limited due to natural and anthropogenic barriers (e.g., mountain ranges, roads, fences, etc.). Although reduced numbers have been reported for almost every pronghorn herd in southern California (Sommer 2012), recent decline has been particularly apparent within the CPNM (Fig 1). Regional information for pronghorn is limited and the regulatory factors affecting survival, fitness and ultimately population size are poorly understood.

The recovery of highly reduced pronghorn populations, such as the population occupying the CPNM, can be limited by low offspring recruitment (Barrett 1984), the developmental stage at which individuals begin to make a reproductive contribution to a population. Although pronghorn commonly produce large numbers of offspring and exhibit the highest reproductive investment of any North American ungulate (Byers and Moodie 1990), survival of postnatal fawns is variable, causing considerable fluctuations in annual recruitment rates (Kohlmann 2004).
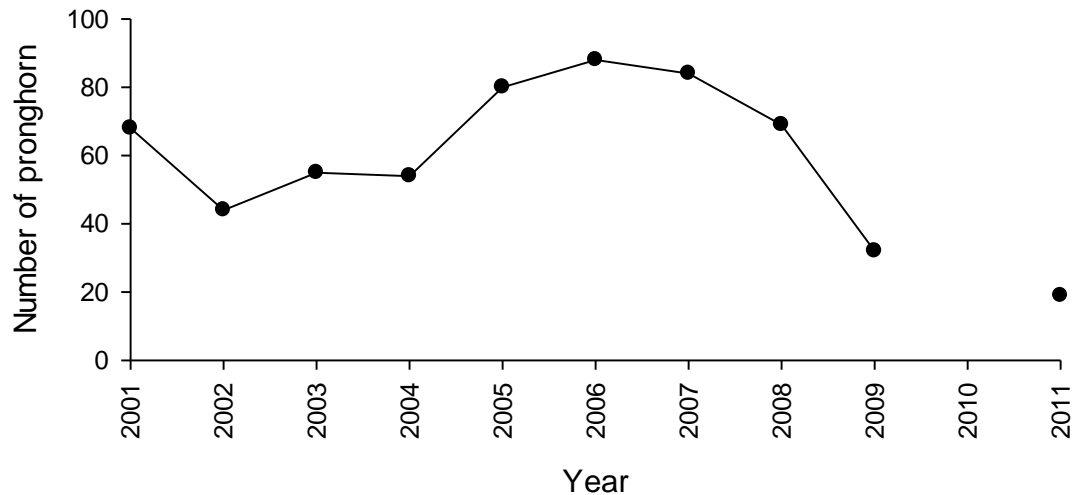
Figure 1. Numbers of pronghorn observed during winter aerial surveys on the Carrizo Plain National Monument (CPNM) from 2001 to 2011. Winter count information for 2010 was not available due to poor weather conditions for flying. The original number of pronghorn released onto the CPNM from 1987 – 1990 was 135 animals and the population estimate for 1995 was 150 animals. Data courtesy of California Department of Fish and Game.

Recruitment is influenced by a combination of density dependent and density independent variables. Low annual precipitation and poor forage quality and abundance reduce offspring production (Oftedal 1985, Price and White 1985, Hansen and Anthony 1999). Disease, adverse weather conditions and insufficient vegetative concealment from predators decrease fawn survival (Kohlman 2004). The biotic and abiotic habitat variables which limit recruitment are enhanced within marginal habitats (McKenzie 1986, Lee et al. 1998). For the CPNM, habitat quality is ranked moderate-to-low for pronghorn (Longshore and Lowrey 2008), indicating that offspring recruitment and ultimately population size may be restricted by conditions at this site.

Population size is of particular concern to resource managers because small populations can suffer from weak or even negative growth rates, referred to as an Allee effect (Fig 2; Allee 1931). The Allee effect greatly enhances the risk of extinction (Stephens et al. 1999, Courchamp et al. 2008a) and therefore has strong implications for wildlife management, conservation and applied ecology. Density dependency in recruitment has been documented for nearly all North American ungulates, including pronghorn (Fowler 1981). However, research has largely focused on the effects of "overcrowding", where increased population size or density decreases recruitment (i.e., "classical" or negative density dependence) (Fowler 1981, Hess 1986, Hess 1999, Pojar 1997). In contrast, a paucity of information is available for "inverse" or positive density dependence in small pronghorn populations. Furthermore, the relationship between recruitment and the Allee effect is understudied. Because individuals of many social species benefit from the presence of conspecifics (Stephens and Sutherland 1999), fitness costs are often generated when aggregate behavior is restricted in low density populations (Courchamp et al. 2008a). For pronghorn, birth synchrony is exhibited to reduce offspring predation (Rutberg 1987, Gregg et al. 2001, Kohlmann 2004). By producing a large number of young during a short interval of time, predator thresholds (e.g., energy and time foraging required) are thought to be saturated. However, the benefits of birth synchrony are density dependent, and in small

populations offspring production may not be sufficient to reduce predation rates. Small populations, with reduced offspring production and increased predation rates would exhibit an Allee effect (Fig. 2).

Information on pronghorn offspring recruitment is critical for evaluating causes of population decline on the CPNM and surrounding region. The primary objectives of this study are to quantify fawn survival, identify causes of mortality, and examine the relationship between offspring recruitment, habitat and population density. We investigate how recruitment is influenced by the availability, as well as the spatiotemporal use of biotic and abiotic habitat variables, including seasonal forage quality, diversity and abundance, water availability, landscape scale topographic features, and climatic conditions. We evaluate density dependence in recruitment by testing for evidence of Allee effects in this population. We then assess birth synchrony as a mechanism for the Allee effect by examining offspring production and survivorship in relation to timing of birth.
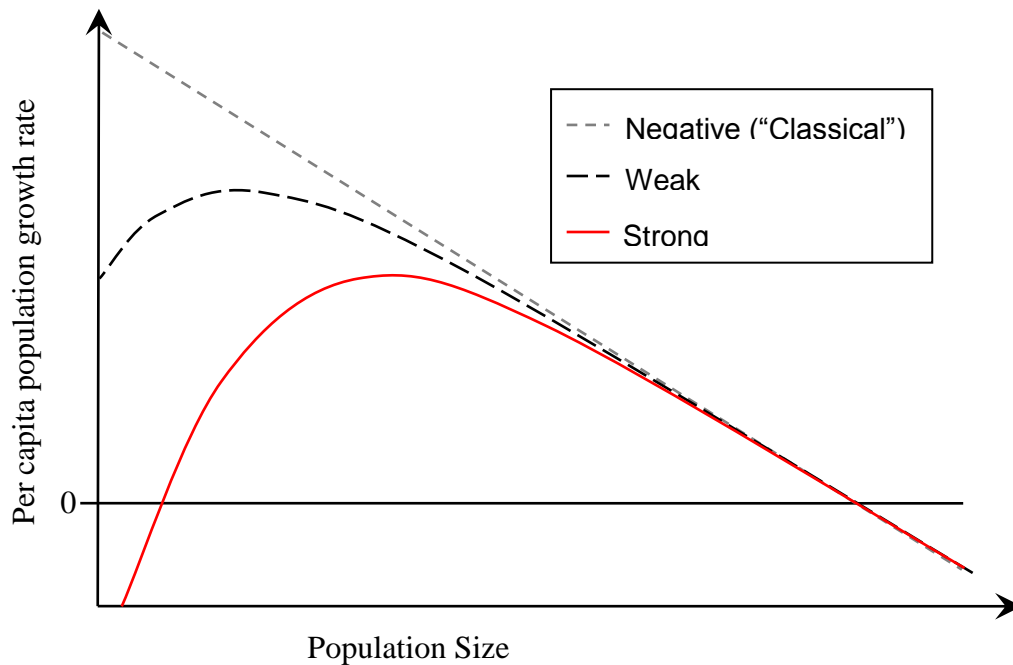

Figure 2. Relationships between population size and per capita growth rate (adapted from Berec et al. 2007). At low population size, the relationship is positive for both weak and strong Allee effects.

Objectives
1. Quantify pronghorn fawn survival.
2. Quantify fawn mortality due to predation and other mortality factors.
3. Determine the effect of birth synchrony on fawn survival and test for Allee effects.
4. Evaluate the relationship between fawn survival and habitat.
5. Assess the effects of precipitation and temperature on fawn survival.
6. Monitor food habits and nutritional quality of pronghorn diets for evaluation of the effect of diet and forage quality on fawn recruitment.

Study area

The Carrizo Plain National Monument (CPNM) is located within the coast range in southeastern San Luis Obispo County, California (Goodwin Education Center: N 35° 11' 23.51", W 119° 51' 47.87"; UTM 35.189864, -119.863298) (Fig 3). The monument encompasses 102,639 hectares (253,628 acres) co-managed by the CDFG, Bureau of Land Management (BLM) and The Nature Conservancy (TNC) (BLM 2011, Sisk et al. 2008). Topography within the monument is primarily composed of an expansive plain bordered by two mountain ranges: the Temblor Range along the northeast boarder and the Caliente Range along the southwest boarder. Elevation along the valley floor averages 615 meters (2,018 ft). The highest elevation is Caliente Peak at 1,556 meters (5,105 ft). Annual rainfall occurs primarily between December and April and can be highly variable among years (Fig. 4; mean = 24.56 cm, SE = 2.31 cm). Average minimum daily temperature during the past two decades since 1992 was 5°C (41°F, SE = 8.72) and average maximum daily temperature was 24°C (75°F, SE = 13.04). Historically, the area was used for dry land wheat farming and is now inundated with non-native annual plant species. Annual grasses, notably brome (*Bromus* spp.) and wild oats (*Avena* spp.) are dominant on the plain. Alkali sink vegetation including saltbush (*Atriplex spinifera*), and iodine bush (*Allenrolfea occidentalis)* are found at the lowest elevations. Juniper-oak cismontane woodland and cismontane juniper woodland and scrub are found in the higher elevations (USFWS 1995).
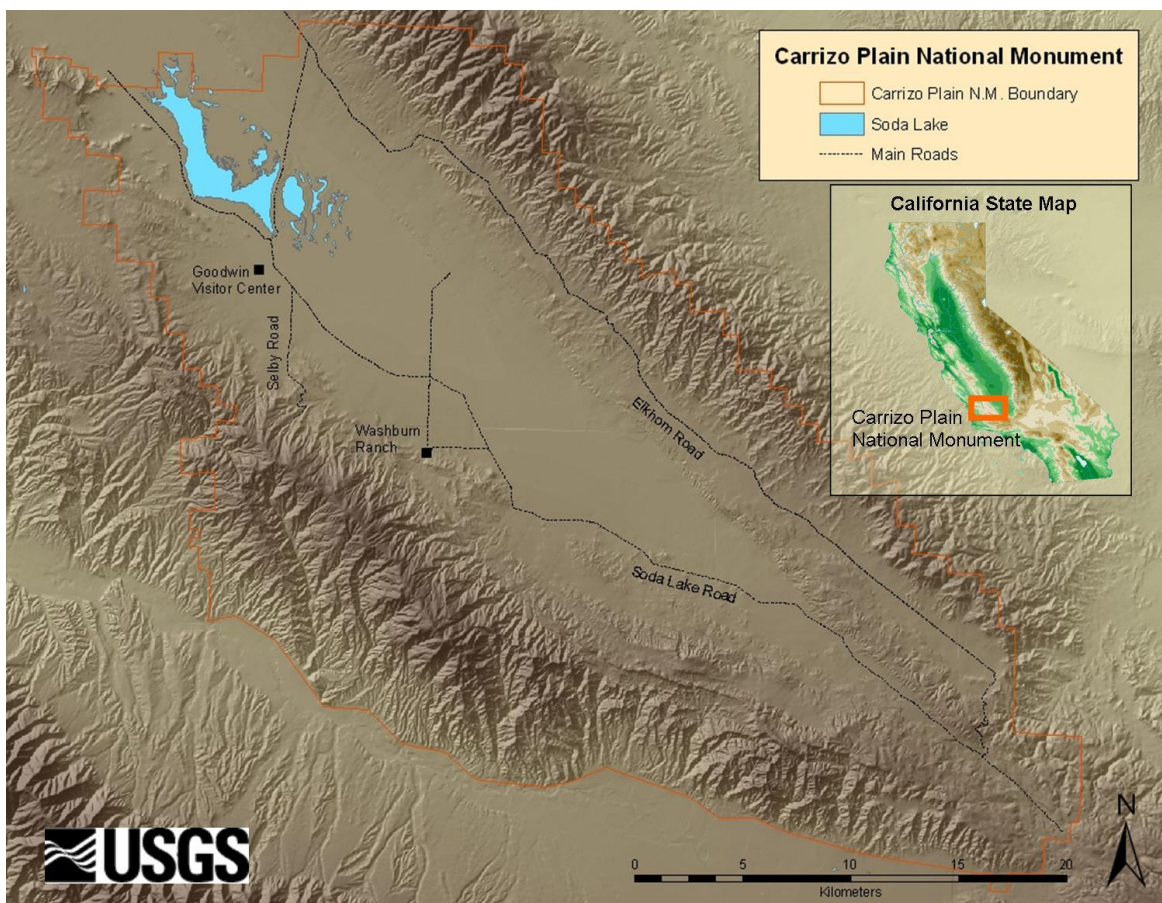

Figure 3. Carrizo Plain National Monument, CA. Goodwin Education Center is located at N 35° 11' 23.51", W 119° 51' 47.87"; UTM 35.189864, -119.863298.
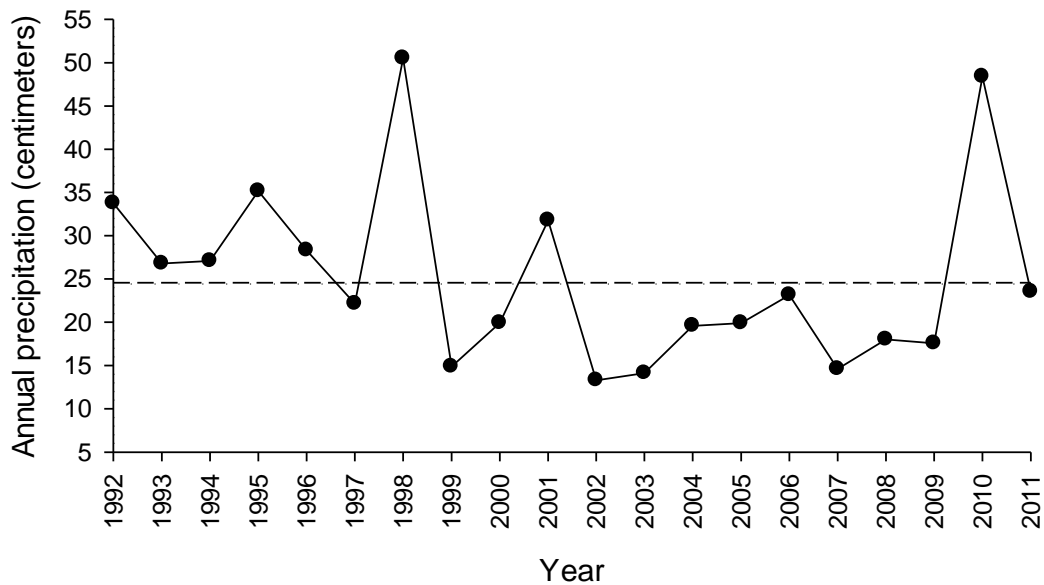
Figure 4. Annual precipitation on the Carrizo Plain National Monument, CA from 1992 to 2011. Mean precipitation (dashed line) was 24.56 centimeters (SE = 2.31 cm) during the 19 year period following original pronghorn translocations. Data was collected from Remote Automatic Weather Stations, Western Regional Climate Center.

Methods

Quantify pronghorn fawn survival

Neonatal pronghorn fawns were equipped with GPS/VHF expandable, breakaway collars during April and May, 2009-2011. Total weight of each collar was ≤ 120 grams. Fawn captures were conducted using methods described in O'Gara et al. (2004) and Gregg et al. (2001). Heidi Zurawka D.V.M., California Dept. Fish & Game, assisted with captures and trained the field crew in fawn processing techniques in 2009. Pronghorn fawns were captured at < 5 days of age. Bedded fawns were approached on foot and a large net (approx. 1 m dia.) was placed gently over the fawn to assure capture and prevent bolting. If a birth was witnessed, capture was conducted at least 4-6 hours afterwards to allow for fawn-doe imprinting. Once captured, every effort was used to minimize stress to the animals. Fawns were blindfolded and kept still to reduce the chance of injury. Surgical gloves, capture net, and collars were all previously stored in local vegetation to minimize human scent. We recorded sex, weight, body measurements, condition of fawns, and estimated the date of birth. For fawns whose birth was not observed, birth date was estimated by behavioral criteria, condition of pelage, hoof and dental development, and desiccation of umbilical cord (see O'Gara et al. 2004). Blood samples (18-20 ml) were collected from individuals that did not appear stressed (e.g. fawns that struggled more than normal). Blood samples were sent to the California Department of Fish and Game Wildlife Investigations Laboratory. All pronghorn fawns observed on the CPNM were monitored daily. Collared fawns were located using VHF telemetry receivers. Positive identification of uncollared fawns was possible through the collaring of a sibling, location, or identifiable pelage of the mother (Byers

1997a). Fawns which lived > 90 days were considered to have been recruited based on abundant evidence from similar studies which have documented that 95% of fawn mortality takes place ≤ 18 days of age (Gregg et al. 2001). Results for survival rates were compared to eighteen other similar studies conducted within 10 different states as reported by O'Gara and Shaw (2004).

In addition to collaring fawns, we conducted standardized road surveys from 2008-2011. The purpose of these surveys was to: 1) monitor the distribution and condition of uncollared fawns and adults; 2) verify count information from flights conducted by the CDFG during that same period; and 3) locate and recorded potential predators of fawns (i.e., coyotes and golden eagles) (predators were recorded for 2010 and 2011 only). The CPNM contains an extensive network of paved and unpaved roads (>150 km in total), so that any one point within suitable pronghorn habitat is no more than 4.2 km from a drivable location. We were able to use binoculars and spotting scopes to effectively survey all pronghorn habitat from vehicles and by accessing areas of elevated topography on foot. Animal locations were calculated using the observer location (*Garmin map*76 handheld GPS unit) and the estimated distance and bearing to the animal. Female pronghorn detected during ground surveys were monitored for the presence of fawns using methods described by Byers (1997a).

We calculated seasonal fawn survival rates using the Kaplan–Meier (K-M) procedure (Kaplan and Meier 1958) modified for staggered entry (Pollock et al. 1989). Due to the small sample size of collared individuals and the large quantity of censored data (i.e., telemetry failure) interpretation of K-M results was limited. However, when we compared K-M survival curves between collared fawns and fawns which were uncollared, but monitored regularly for survival, we found that results did not differ. We therefore grouped all fawns born during individual seasons and then compared seasons using a log rank procedure.

Quantify fawn mortality due to predation and other mortality factors.
Dead fawns were recovered as quickly as possible to determine whether death was due to predation and if so, to identify the predator species using criteria described in O'Gara and Shaw (2004). When possible, dead fawns were taken to the California Department of Fish and Game's Wildlife Investigations Laboratory for necropsy results.

Determine the effect of birth synchrony on fawn survival and test for Allee effects.
To examine the degree of synchronicity for annual birth distributions we divided the range of days in which births occurred for each year into four equal periods using the first, second and third quartiles. We then totaled the number of births which occurred during each of the four periods. The two periods with the most number of births were considered peak periods and the two periods with the least number of births were considered non-peak periods. We defined birth synchrony as a distribution with two adjacent peak periods (e.g., the first and second periods are peak). Distributions in which the two peak periods were separated by one or more non-peak periods were considered to be asynchronous. The survival rates for fawns born during peak and non-peak periods were then compared to determine the effect that timing of birth had on recruitment (Gregg et al. 2001).

To test for Allee effects, we investigated the density dependent feedback of population size on the logarithmic per capita population growth rate (Hoffman et al. 2010). Population size for the

CPNM and CV herds were estimated using winter count totals from aerial surveys conducted by the CDFG from 2000 to 2011. Population size was used instead of population density because the two areas occupied by each herd are similar in size. We compared information from aerial counts to information from ground surveys to assess the accuracy of population estimates. Logarithmic per capita population growth rate ($\log(g(N))$) was calculated using log transformed data from the discrete-time model of population dynamics ($g(N) = \log(N_{t+1}/N_t)$; where N_t represents the population size at time t (Courchamp et al. 2008b).

Evaluate the relationship between fawn survival and habitat.
We developed two separate binary logistic regression models to explore the best combination of biotic and abiotic environmental parameters for predicting 1) fawn habitat selection and 2) fawn survival (Hosmer and Lemeshow 2000). Akaike's information criteria adjusted for small sample size (AIC_c) was used for model selection (Burnham and Anderson 2002). The log-likelihood estimates from each of the alternative logistic regression models were used to determine AIC_c and ΔAIC_c values. We used the AIC_c differences to rank the set of candidate models. We considered approximating models with ΔAIC_c of ≤ 2 as possible competing models. We used Akaike weights (w_i) and evidence ratios to assess the relative strength of evidence for each model. For both models, we performed all geographical information system (GIS) analyses using ArcMap 9.3 (ESRI 2008).

The fawn habitat selection model compared the relationship between fawn and random locations (dichotomous response/dependent variables) and a suite of macro- and microhabitat parameters (explanatory/independent variables). We considered microhabitat characteristics to be located within a spatial scale small enough to elicit a response by individual fawns. Microhabitat was defined exclusively as the area within a 100 meter radius of a fawn and included measurements of vegetation height and composition (i.e., forb, grass, shrub, bare ground), as well as adult and fawn visibility. Measurements were made at fawn and random locations, along four equidistant compass directions at 10 meter intervals to 50 meters and then again at 100 meters (modified from Canon and Bryant 1997). Visibility was defined as the proportion of a 1 meter measuring stick (located at the center of each plot) visible at fawn height (0.5 m) and adult height (1 m). Macrohabitat characteristics were considered to be landscape-scale features which would potentially influence doe habitat selection but not necessarily fawn habitat selection. Macrohabitat explanatory variables were generated from six spatially explicit environmental GIS data layers and included slope of terrain and linear distances to active water sources, fences, saltbush (*Atriplex* spp.), high-use main roads (Soda Lake Rd., Panorama Rd., Selby Rd. and Elkhorn Rd) and all roads (small roads as well as main roads.)

The fawn survival model compared the relationship between locations of fawns $\leq$ or > 17 days of age (dichotomous response/dependent variable) and the same spatially explicit, landscape scale macrohabitat features used in the fawn habitat survival model (explanatory/independent variables). Based on information from Gregg et al. 2001, that the majority (95%) of fawn mortalities take place ≤ 17 days of age, as well as corresponding evidence from our survival data (see *Results*), we considered that fawns >17 days of age would have a higher expectancy for survival than fawns < 17 days of age; and that habitat selection between these two groups would vary accordingly to influence survival.

Assess the effects of precipitation and temperature on fawn survival.
Weather information, consisting of annual and seasonal precipitation and temperature, was collected from the Carrizo Remote Automated Weather Station (RAWS) and compared to annual offspring production and survival observed on the CPNM from 2009 to 2011. Climatic parameters were not included in the fawn survival model because the study period was not long enough to produce adequate variability in the data (i.e., data could not converge algorithmically).

Monitor food habits and nutritional quality of pronghorn diets for evaluation of the effect of diet and forage quality on fawn recruitment.
Pronghorn diets were estimated using micro-histological identification of plant epidermal fragments in fecal material. Fecal samples were collected from ten individuals monthly, oven-dried and ground in a Wiley mill through a 1 mm mesh screen. A one-gram subsample was then taken from each fecal sample and composited for analysis by Wildlife Habitat Nutrition Laboratory, Washington State University. Percent fecal nitrogen (FN) and fecal diaminopimelic acid (DAPA) were used as an index of diet quality (Goldsmith 1988, Wehausen 1995, Osborn and Ginnett 2001). Percent diet composition was calculated from the amount of each forage item detected in the diet. We used diet composition results to collect above ground samples of forage species consumed by pronghorn.

Plant biomass and forage availability within the CPNM was measured along 23, 50-meter random transects during spring, summer and winter 2008-2011. Plant composition of above-ground annual vegetation was documented and collected within ten 0.5 meter plots evenly distributed along each transect. Plants were sorted by forage class (i.e., grasses, forbs and shrubs). Forbs (i.e., forbaceous plants) are considered to be herbaceous plants that are not grasses (Yoakum 2004b). Plant samples were weighed immediately after collection, dried, and then reweighed to obtain dry biomass weight and preformed water content (i.e., water contained in forage plants). Nutritional analyses of plant samples were conducted by the Washington State University Wildlife Habitat Nutrition Laboratory. Analyses for nutritional content of forage included, in vitro digestible dry matter (IVDDM), gross energy (cal/g), percent crude protein, percent crude fat, percent neutral detergent fiber, percent acid detergent fiber, percent acid detergent lignin, percent total ash, and percent acid insoluble ash. Available vegetative composition, diet composition, and preference ratings (diet composition divided by available vegetative composition) for forbs, grasses and shrubs were calculated and compared to that for North American grassland and shrubsteppe biomes as reported by Yoakum (2004c).

Results
Quantify pronghorn fawn survival
Forty-five pronghorn fawns were born on the CPNM during three seasons from 2009 to 2011. Of these individuals, 20 (7 males and 13 females) were equipped with GPS/VHF collars and released. Mean age at capture was 2.07 days (SE = 0.33). Body measurements and processing data for each fawn can be found within Appendix A. Survival between male and female collared fawns did not differ (z = -0.32, p = 0.75). The remaining 11 uncollared fawns were monitored through field observation. Percent survival of collared fawns (20.0%) and uncollared fawns (32%) did not differ (z = -0.25, p = 0.81). Percent survival of all fawns on the CPNM (26.7%) did not differ from that found for other populations (29.4%, n = 995) as reported by O'Gara and

Shaw (2004) ($z = 0.22$, $p = 0.82$) (Table 1). Annual fawn productivity and survival was variable across years (mean productivity = 15.0 fawns, SE = 3.5 and mean survival = 30.7%, SE = 8.5) (Table 1). Of 13 recovered collars, 10 functioned properly while deployed (i.e., consistently recorded locations); and of these 10 functioning collars, 9 were from deceased fawns. The mean number of days lived for the 9 deceased collared fawns was 14.4 days (SE = 2.9) and all but one of these fawns died at ≤ 18 days of age. Results for the Kaplan-Meier survival curve (Fig. 5) indicated that 50% of fawn mortality occurred prior to 20 days of age and that the greatest rate of mortality took place between 16 and 18 days. Kaplan-Meier survival curves did not differ between years (Log-Rank Statistic = 3.34, DF = 2, P = 0.19).

Table 1. Fawn productivity and survival (> 90 days) for three consecutive seasons, from 2009 to 2011, on the Carrizo Plain National Monument, CA.

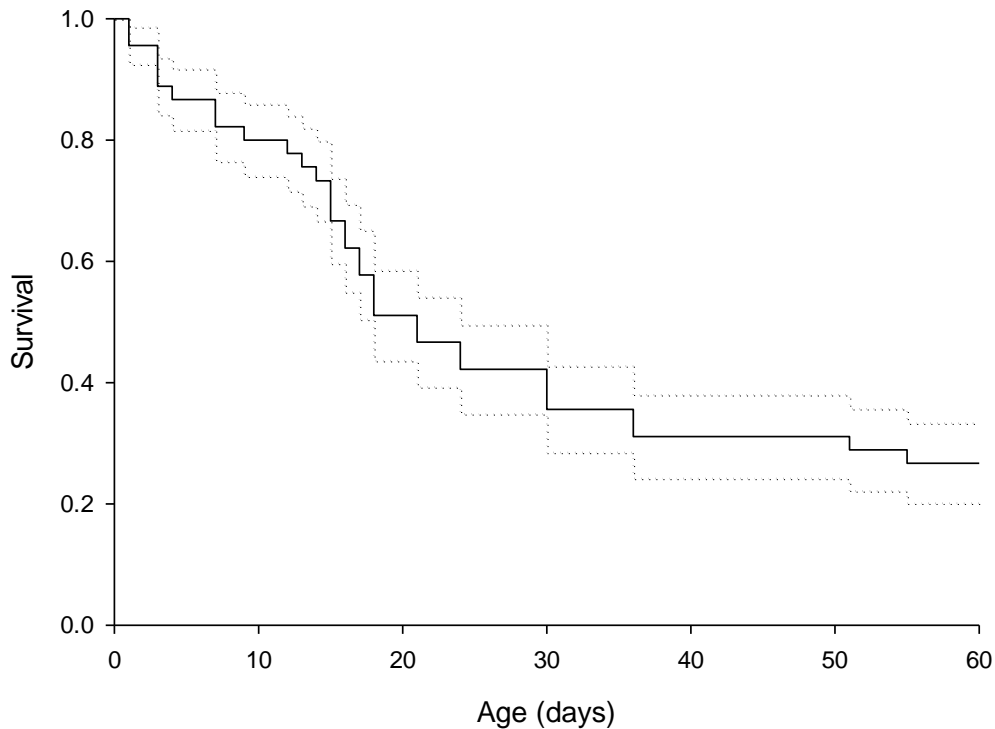| Year	Total fawns born	Total fawns survived (%)
2009	22	3 (13.6)
2010	12	5 (41.7)
2011	11	4 (36.4)
Total	45	12 (26.7)

Fig 5. Survival curve for pronghorn fawns born on the Carrizo Plain National Monument, CA during 2009, 2010 and 2011. Survival rate was calculated as proportion of fawns alive at each age class. Upper and lower confidence intervals (dotted lines) were calculated using Kaplan-Meir standard errors.

Quantify fawn mortality due to predation and other mortality factors.
Causes of mortality for the 20 collared fawns and 1 uncollared fawn included predation (28.6%; n = 6), health-related issues (0.1%; n = 2) and undetermined causes (61.9%; n = 13). For the 6 predator related mortalities, we detected predation by coyote (n = 6) and golden eagle (n = 1). Results from laboratory necropsies performed for the two health-related mortalities indicate that death was caused by an infected umbilical cord for one individual and a lacerated liver (possibly from being stepped on by its mother) for the other (Appendix B).

To evaluate the potential for additional predator related mortalities to have occurred, we analyzed age-specific mortality and movement patterns of fawns that did not survive. Byers (1997b) reported that fawn mortality was highest for individuals between 11 and 20 days; and suggested that, as fawns develop, increases in movement make individuals more visible to predators. On the CPNM, fawns made significant increases in movement between 16 to 18 days of age (Fig. 6). During that same period, the mortality rate was higher than for any other ages (Fig. 5). Eight of the 10 mortalities occurred between 16 and 18 days of age, indicating that mortality risk may have been associated with increased movement.
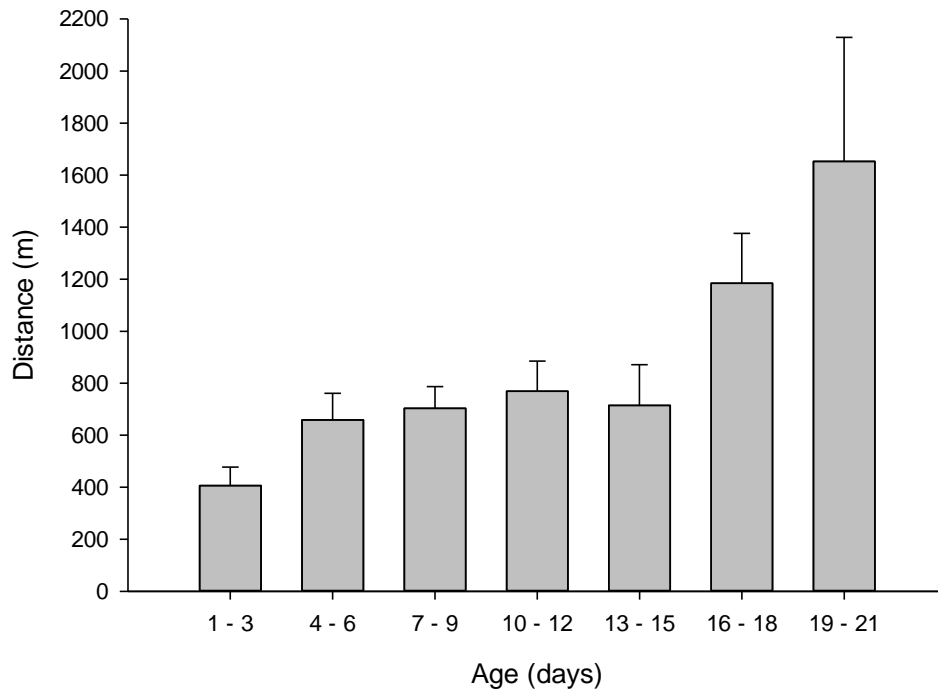

Figure 6. Age-specific movement information for GPS-collared pronghorn fawns on the Carrizo Plain National Monument, CA from 2009-2011. Distances represent the mean number of meters moved per day, in two hour intervals, by fawns in each respective age class. Distances differed across age classes (H = 17.77, df = 6, p = 0.007) with significance detected between age $1-3$ days and $19-21$ days (p < 0.05).

Determine the effect of birth synchrony on fawn survival and test for Allee effects.
Births for all three seasons occurred within a one month period, between April 25 and May 25. The date range and synchronicity of fawn birth distributions appeared to vary between years (Fig. 7). The mean range in which births took place was 22.7 days (SE = 6.4). Birth synchrony was detected for the first two years, during 2009 and 2010, where peak offspring productivity occurred during the first two quarters of each year's respective birth distribution (before quartile 1 and between quartile 1 and 2). Birth synchrony was not detected for 2011, where peak periods of offspring productivity occurred at the beginning (before quartile 1) and at the end (after quartile 3) of the birth distribution. Survival was higher during peak periods than non-peak periods (Table 2); all 12 surviving fawns in the study were born during peak periods and none were born during non-peak periods. Survival was not related to overall offspring production across the three years ($\chi^2 = 6.00$, df = 4, p = 0.20).
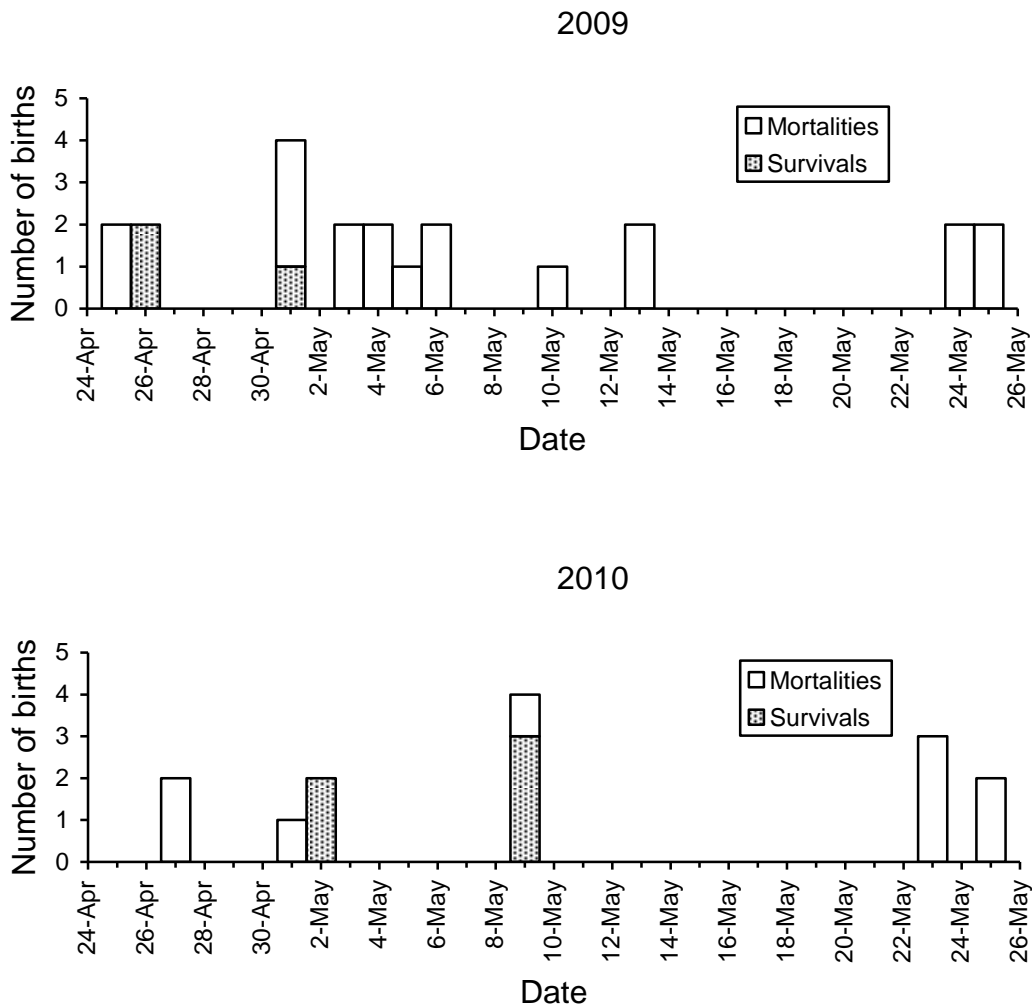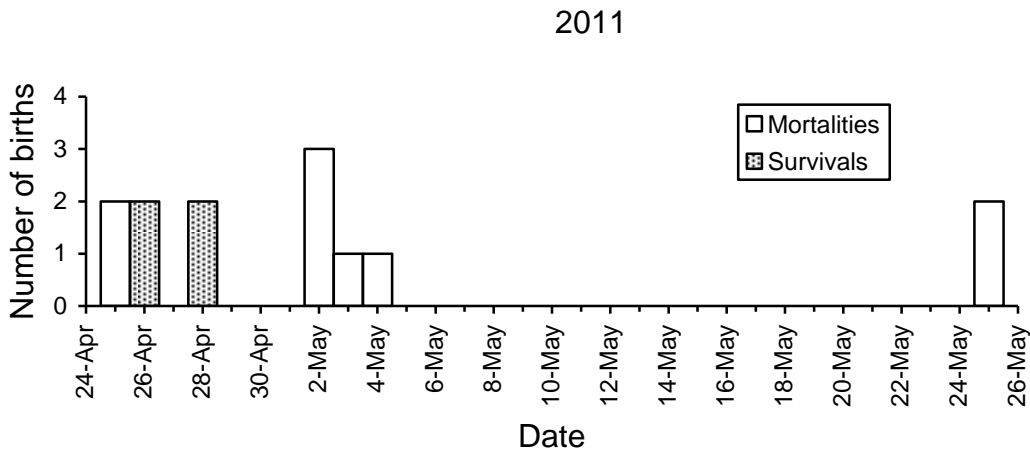

2009

2010

Figure 7. Pronghorn fawn birth distribution for 2009, 2010 and 2011 on the Carrizo Plain National Monument, CA. Survivals (shaded bars) and mortalities (open bars) of individuals are indicated. Birth synchrony was detected for 2009 and 2010, but not for 2011.

Table 2. Number of survivals and mortalities of fawns born during peak and non-peak periods on the Carrizo Plain National monument, CA.

Year	Survivals		Mortalities		Total
	Peak	*Non-peak*	*Peak*	*Non-peak*	
2009	3	0	12.5	6.5	22
2010	5	0	4	3	12
2011	4	0	2	5	11
Total	12	0	18.5	14.5	45

Patterns of pronghorn abundance and distribution appeared consistent between ground and aerial surveys (Fig. 8) conducted during the fawning seasons from 2009 to 2011. From 2000 to 2011,we found a significant negative relationship between population size and per capita population growth rate for pronghorn across the entire Carrizo Plain (i.e., CPNM and CV herds combined) (f = 5.93 , df = 1, adj r^2 = 0.33 ,p = 0.04). Independently, however, this relationship was only significant for the CV herd (f = 21.70 , df = 1, adj r^2 = 0.67 ,p = 0.001) (Fig. 9).
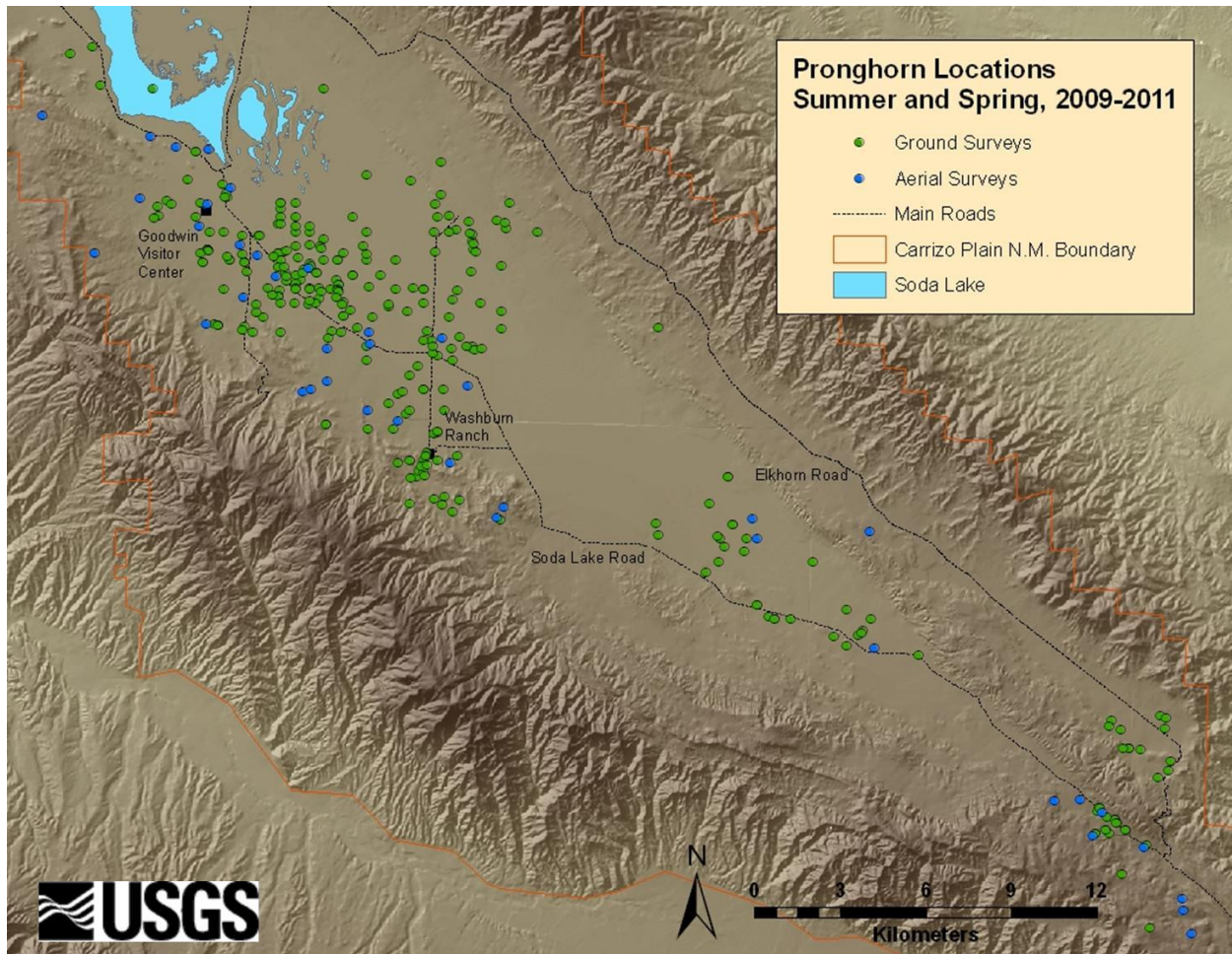
Figure 8. Pronghorn observations on the Carrizo Plain National Monument, CA collected from ground surveys (green circles) and aerial surveys (blue circles) during spring and summer 2009-2011). Points represent single observations of one or more animals (mean = 3.60 individuals per location, range = 1-16 individuals per location).
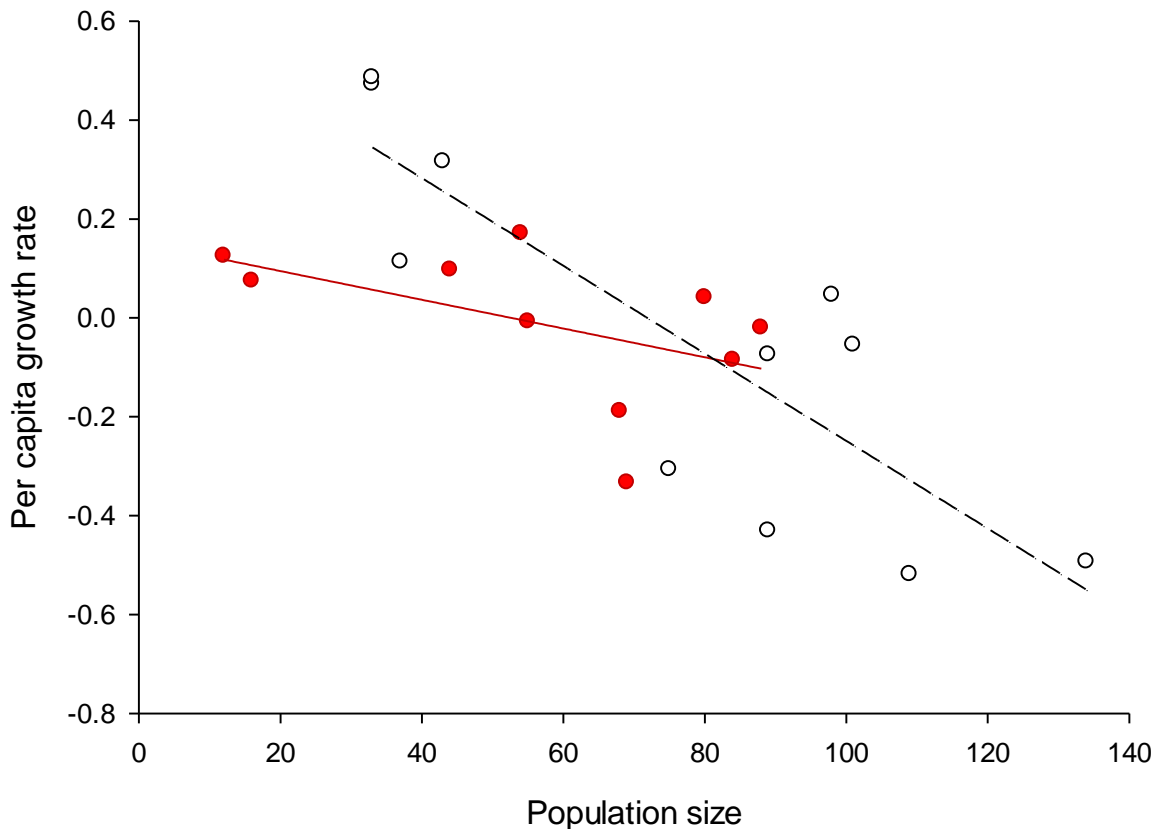
Figure 9. The logarithmic per capita growth rate relative to population size for pronghorn within the Carrizo Plain National Monument (closed circles and solid line; $r^2 = 0.25$, f = 2.67, df = 1, p = 0.14) and pronghorn in California Valley (open circles and dashed line; $r^2 = 0.71$, f = 21.70, df = 1, p = 0.001). Information reflects winter count totals from aerial surveys conducted by the California Department of Fish from 2000-2011.

Evaluate the relationship between fawn survival and habitat.
To model fawn habitat selection, eight candidate models were developed using 70 locations from collared individuals and 61 random locations (Table 3). The habitat parameters used in the global model are indicated at the bottom of Table 3. Two candidate models, Model 1 ($w_i = 0.56$) and Model 2 ($w_i = 0.36$), showed substantial support as the best approximating models ($\Delta AIC_c < 2$). Parameter estimates (β), standard errors (SE) of the estimates, odds ratios, and 95% confidence intervals (CI) for the odds ratios of the variables in the two models are shown in Table 4. Model 1 showed that fawn locations were positively associated with increased forb composition and fawn visibility (height 0.5 m) at 100 m distance; and negatively associated with increased vegetation height at 5m, fawn visibility at 5 m and 50 m, slope of terrain, and linear distance to saltbush and water. Model 2, consisted of the same parameters and respective positive/negative associations as Model 1, excluding forb composition at fawn locations and fawn visibility at 50 m. Model 1 and Model 2 parameters which could be measured using a GIS, including slope of terrain and linear distances to water sources and saltbush, were used to create a generalized map of fawn habitat selection (Fig. 10).

The two best approximating models for fawn habitat selection included:

Model 1: Fawn habitat = 7.802 - (0.002) Distance to saltbush - (0.001) Distance to water - (0.424) Percent slope of terrain - (0.04) Fawn visibility at 5 meter distance - (0.027) Fawn visibility at 50 meter distance + (0.053) Fawn visibility at 100 meter distance + (0.02) Forb cover at fawn location - (0.045) Vegetation height at 5 meter distance.

Model 2: Fawn habitat = 7.892 - (0.002) Distance to saltbush - (0.001) Distance to water - (0.225) Percent slope of terrain - (0.046) Fawn visibility at 5 meter distance + (0.031) Fawn visibility at 100 meter distance - (0.041) Vegetation height at 5 meter distance.

Table 3. Comparison and relative ranking of candidate models for pronghorn fawn habitat selection on the Carrizo Plain National Monument, California from 2009 to 2011. Akaike's Information Criteria (AIC) corrected for small sample sizes (AIC_c) was used for model selection. Included for each candidate model are values for log-likelihood, number of parameters (k), AIC_c values, ΔAIC_c values, and Akaike weights (w_i). Relative ranking of models was determined using ΔAIC_c.

	Model	-2LogL	k	AIC_c	ΔAIC_c	w_i
1	dsb+dw+ps+fvis5+fvis50+fvis100+f0+ht5	98.33	8	115.51	0	0.5593
2	dsb+dw+ps+fvis5+fvis100+ht5	103.74	6	116.41	0.91	0.3552
3	dsb+dw+fvis5+fvis100+f0	109.57	5	120.05	4.54	0.0578
4	Global model[a]	83.51	17	122.93	7.42	0.0137
5	dsb+dw+fvis100	116.76	3	122.95	7.44	0.0135
6	dsb+dw+f0	123.44	3	129.63	14.12	0.0005
7	dsb+dw	128.57	2	132.66	17.16	0.0001
8	dw+ps+ht5+fvis100+f0	125.73	5	136.21	20.70	0.00002

[a]Global model included distances to saltbush (dsb), water (dw), main roads (dmr), and fences (df); percent slope of terrain (ps); fawn visibility at fawn location (fvis0) and at distances of 5 meters (fvis5), 10 meters (fvis10), 50 meters (fvis50) and 100 meters (fvis100); forb cover at fawn location (f0), grass cover at fawn location (g0), and cover at distances of 5 meters for forbs (f5), grasses (g5) and shrubs (s5); vegetation height at fawn location (ht0) and at 5 meters distance (ht5).

Table 4. Parameter estimates (β), standard errors (SE) of the estimates, odds ratios, and 95% confidence intervals (CI) for the odds ratios of the variables in the two best approximating models for the occurrence of pronghorn fawns on the Carrizo Plain National Monument, California.

Effect	β	SE	Odds ratio	95% CI
Model 1:				
dsb	-0.002	0.001	0.998	0.996-0.999
dw	-0.001	<0.001	0.999	0.998-1.000
ps	-0.424	0.256	0.654	0.396-1.080
fvis5	-0.040	0.020	0.961	0.924-1.000
fvis50	-0.027	0.026	0.973	0.924-1.025
fvis 100	0.053	0.027	1.054	1.000-1.111
f0	0.020	0.010	1.021	1.001-1.040
ht5	-0.045	0.023	0.956	0.915-0.999
Model 2:				
dsb	-0.002	0.001	0.997	0.997-0.999
dw	-0.001	<0.001	0.998	0.998-0.999
ps	-0.225	0.191	0.550	0.550-1.161
fvis5	-0.046	0.020	0.919	0.919-0.993
fvis 100	0.031	0.012	1.011	1.011-1.054
ht5	-0.041	0.021	0.921	0.921-1.001

Variables include distance to saltbush (dsb), distance to water (dw), percent slope of terrain (ps), fawn visibility at distances of 5 meters (fvis5), 50 meters (fvis50) and 100 meters (fvis100), forb cover at fawn location (f0), and vegetation height at 5 meters (ht5).
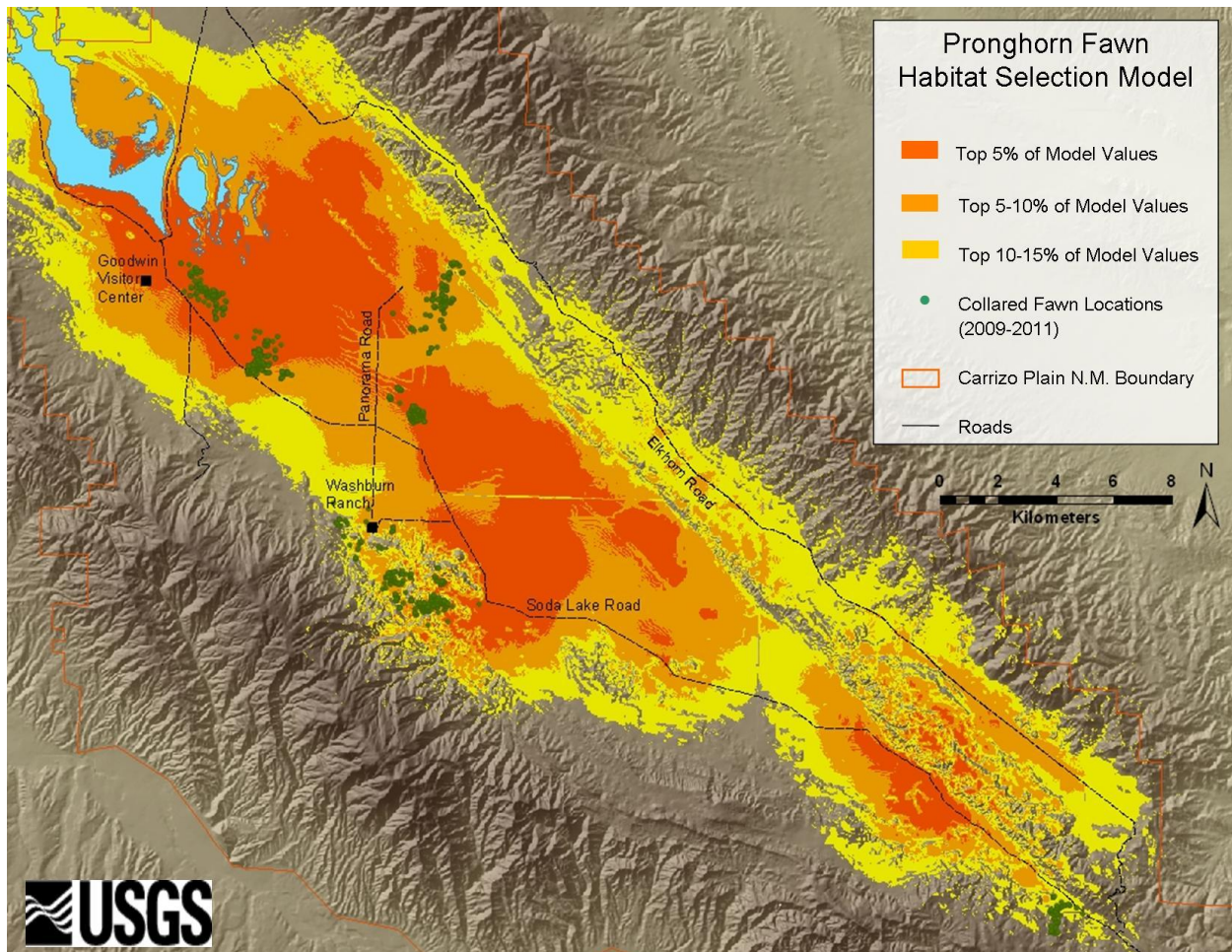
Figure 10. Generalized pronghorn fawn habitat selection model for the Carrizo Plain National Monument, CA. Included are variables from the best approximating binary logistic regression model for predicting fawn habitat and which could be mapped using a GIS (i.e., linear distance to water and saltbush communities and percent slope of terrain). The top 15% of model values are indicated.

To model fawn survival we used 1,417 locations from 10 GPS collared individuals to develop six candidate models (Table 5). The parameters used in the global model of fawn survival are located at the bottom of Table 5. Two candidate models, Model 1 ($w_i = 0.55$) and Model 2 (global model; $w_i = 0.32$), showed support as the best approximating models ($\Delta AIC_c < 2$). Parameter estimates (β), standard errors (SE) of the estimates, odds ratios, and 95% confidence intervals (CI) for the odds ratios of the variables in the two models are shown in Table 6. Model 1 showed that locations of individuals which lived greater than 17 days were positively associated with increased slope and distance to main roads; and negatively associated with increased linear distance to water, fences, and all roads. Model 2, in addition to the same parameters and respective positive/negative associations as Model 1, showed a negative association with linear distance to saltbush. The global model was mapped to include the effect of saltbush on fawn survival (Fig. 11). Locations of both collared and uncollared fawns were dispersed throughout the CPNM; located on both the north and south ends of the plain, as well as on the east and west sides of the plain. Locations for the 10 GPS collared fawns used in the

models are indicated in Fig 12. The mean fawning area for these collared fawns was 0.05 km^2 (SE = 0.01 km^2).

The two best approximating models of fawn survival included:
Model 1: Survival = 1.235 + (0.0009) Distance to main roads - (0.0028) Distance to all roads - (0.0016) Distance to fences - (0.0004) Distance to water + (0.0403) Percent slope of terrain

Model 2: Survival = 1.530 + (0.0008) Distance to main roads - (0.0028) Distance to all roads) - (0.0018) Distance to fences - (0.0002) Distance to saltbush - (0.0004) Distance to water) + (0.0509) Percent slope of terrain.

Table 5. Comparison and relative ranking of candidate models for pronghorn fawn survival on the Carrizo Plain National Monument, CA from 2009 to 2011. Akaike's Information Criteria (AIC) corrected for small sample sizes (AIC$_c$) was used for model selection. Included for each candidate model are values for log-likelihood, number of parameters (k), AIC$_c$ values, Δ AIC$_c$ values, and Akaike weights (w_i). Relative ranking of models was determined using Δ AIC$_c$.

	Model	-2LogL	k	AIC$_c$	ΔAIC$_c$	w_i
1	dmr+dar+df+dw+ps	478.20	5	488.25	0	0.5540
2	Global model[a]	477.30	6	489.36	1.12	0.3172
3	dmr +dar+df+dw	483.16	4	491.19	2.94	0.1275
4	dmr+ dar+df	494.34	3	500.35	12.11	0.0013
5	dmr + dar	508.19	2	512.19	23.95	< 0.0001
6	dmr +dw+ps	527.97	3	533.98	45.74	< 0.0001

[a]Global model included percent slope of terrain (ps) and distances to saltbush (dsb), water (dw), main roads (dmr), all roads (dar) and fences (df).

Table 6. Parameter estimates (β), standard errors (SE) of the estimates, odds ratios, and 95% confidence intervals (CI) for the odds ratios of the variables in the two best approximating models of pronghorn fawn survival on the Carrizo Plain National Monument, CA.

Effect	β	SE	Odds ratio	95% CI
Model 1:				
dmr	0.001	<0.001	1.001	1.000-1.001
dar	-0.003	0.001	0.997	0.996-0.998
df	-0.002	<0.001	0.998	0.997-0.999
dw	-0.0004	<0.001	1.000	0.999-1.000
ps	0.0403	0.019	1.041	1.004 -1.080
Model 2:				
dmr	0.001	<0.001	1.001	1.000-1.001
dar	-0.003	0.001	0.997	0.996-0.998
df	-0.002	0.001	0.998	0.997-0.999
dw	-0.0004	<0.001	1.000	0.999-1.000
ps	0.051	0.022	1.052	1.009-1.097
dsb	-0.002	<0.001	1.000	0.999-1.000

Variables include percent slope of terrain (ps) and distances to water (dw), main roads (dmr), all roads (dar), fences (df) and saltbush (dsb).
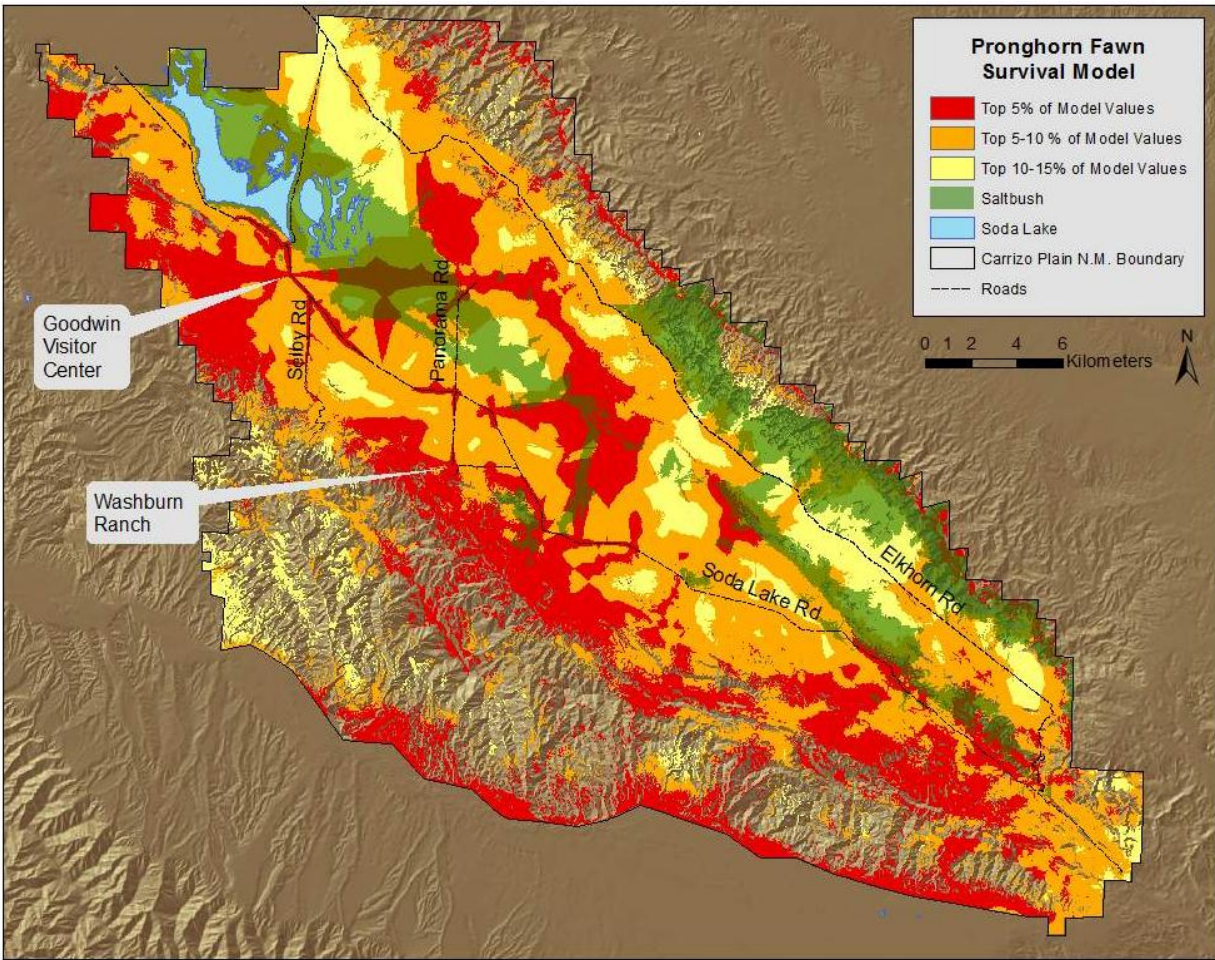
Figure 11. Pronghorn fawn survival model for the Carrizo Plain National Monument, CA. Model parameters include slope of terrain and distances to water sources, saltbush (*Atriplex* spp.), fences, small dirt roads, and high use main roads (Soda Lake Rd., Elkhorn Rd., Panorama Rd. and Selby Rd.). Indicated are the top 15% of model values within the CPNM boundary.
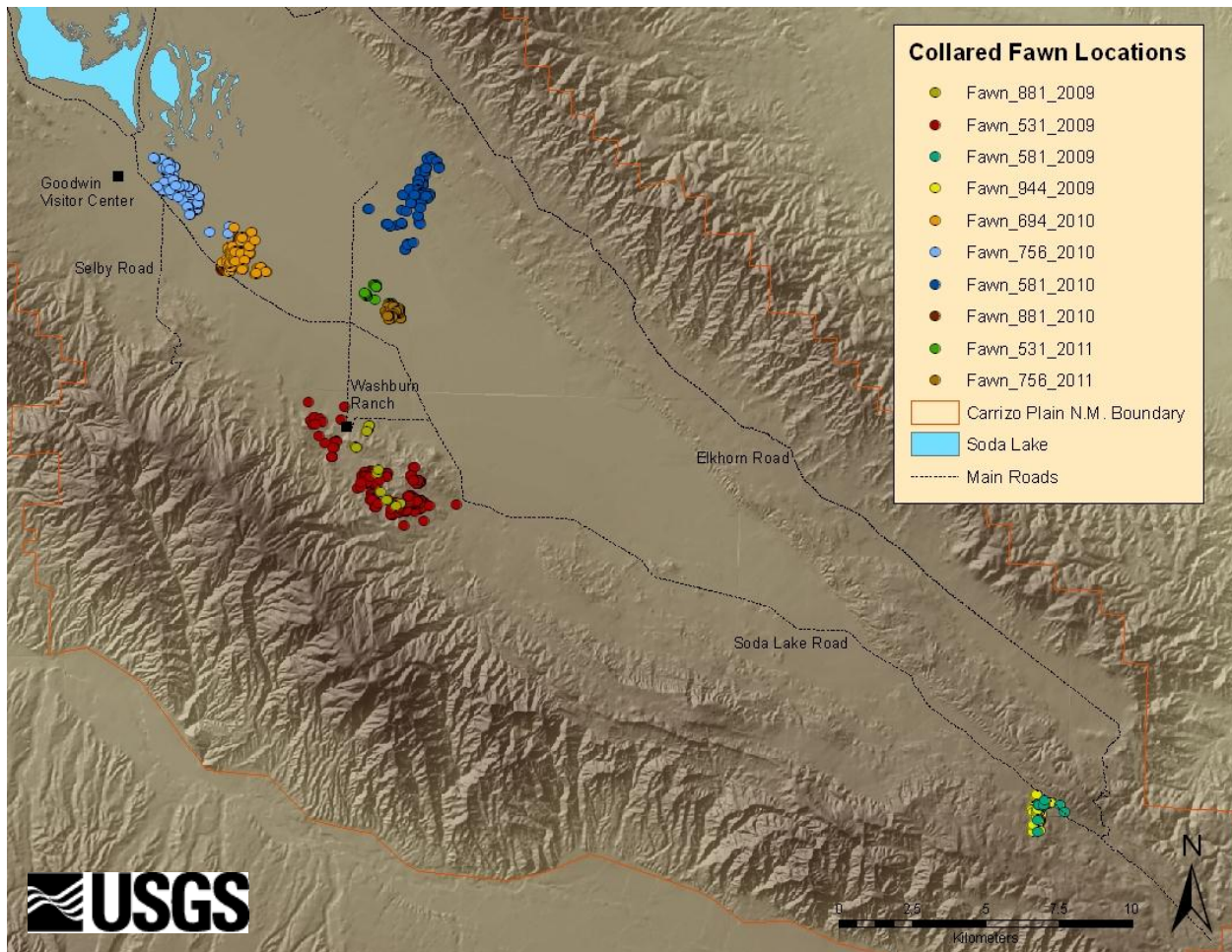
Figure 12. Locations of ten pronghorn fawns collared on the Carrizo Plain National Monument, CA from 2009-2011.

Assess the effects of precipitation and temperature on fawn survival.

Seasonal precipitation and temperature, as well as annual fawn productivity and survival, varied considerably during the study (Table 7). Of the three study years, 2009 had the lowest total seasonal precipitation (15.80 cm; 6.22 in) and the greatest summer average high temperature (31.24°C; 88.23°F). Although annual fawn production was highest during 2009 (22 fawns), annual survival of fawns was lowest (14%). Measurements of seasonal precipitation and summer high temperature, as well as fawn productivity and survival were similar for 2010 and 2011 (Table 7). Mean annual precipitation during the study (26.87 cm, SE = 14.61 cm; 10.58 inches, SE = 5.75 in) exceeded the mean annual precipitation during the past 20 years (24.56 cm, SE = 10.59; 9.67 in; SE = 4.17 in). However, rainfall in 2010 (48.39 cm; 19.05 in), was exceptionally high and represented the wettest year on record since 1998 (50.50 cm; 19.88 inches). In contrast, annual precipitation for 2008, 2009, and 2011 (18.01 cm, 17.58 cm, 23.52 cm, respectively; 7.09 in, 6.92 in and 9.26 in, respectively), were all lower than mean annual precipitation for the past 20 years.

Table 7. Fawn productivity and survival in respect to seasonal precipitation (precip.; Centimeters) and temperature (temp.; Celsius) from fall 2008 to summer 2011 on the Carrizo Plain National Monument, CA.

Year	Number of fawns born	Number of fawns survived	Fall[1] precip.	Winter[2] precip.	Spring precip.	Summer precip.	Total[3] precip.	Summer avg. high temp.
2009	22	3 (14 %)	0.00	6.68	9.04	0.08	15.80	31.24
2010	12	5 (42%)	0.36	16.97	11.61	0.58	29.51	29.02
2011	11	4 (36%)	4.60	21.97	13.16	2.01	41.73	28.32

[1]Fall = August through October of previous year
[2]Winter = November and December of previous year through January.
[3]Total = fall of previous year through summer.

Monitor food habits and nutritional quality of pronghorn diets for evaluation of the effect of diet and forage quality on fawn recruitment.
Pronghorn consumed more than 50 different individual forage items (Appendix C). At least 42 different plant taxa were identified in the diet, including 26 species of forbs, 9 species of grasses and 8 species of shrubs. Principle forage items (Table 8) comprised ≥ 5% of the dietary composition for any one season. Principle forage items among forbs included *Astragalus* spp., *Camissonia* spp., *Erodium* spp., *Lotus* spp., Aster family flower, Borage family, and legume pod; among grasses were *Avena* spp. and *Bromus* spp.; and for shrubs was *Atriplex* spp. Among principle forage items, *Erodium* spp. comprised >20% of the diet for all seasons; and *Astragalus* spp., Aster family flower, and *Atriplex* spp. represented ≥ 10% of the dietary composition for at least one season.

Table 8. Percentage of principle forage items found in the diet of pronghorn on the Carrizo Plain National Monument, CA during 2008 and 2009. Principle forage items comprised ≥ 5% of the dietary composition for any one season. Diet composition was determined by microhistological analysis of pronghorn fecal samples. Standard error values are indicated within parentheses.

Forage item	Spring (Feb – Apr)		Summer (May – Jul)		Fall (Aug – Oct)		Winter (Nov – Jan)	
Forbs								
Astragalus spp.	12.0	(6.6)	4.7	(1.3)	6.1	(1.1)	9.0	(2.5)
Camissonia spp.	4.4	(1.3)	9.6	(2.5)	6.9	(2.1)	5.8	(2.8)
Erodium spp.	20.9	(1.0)	21.0	(2.4)	21.4	(4.3)	21.3	(5.0)
Lotus spp.	5.4	(2.4)	4.3	(1.2)	6.8	(1.6)	5.1	(2.8)
Aster family flower	2.8	(1.2)	9.2	(3.1)	10.0	(8.0)	3.4	(1.8)
Borage family	2.2	(0.1)	7.8	(2.3)	8.1	(3.4)	1.4	(0.7)
Legume pod	1.0	(0.7)	2.1	(0.7)	6.0	(1.7)	0.7	(0.5)
Grasses								
Avena spp.	2.8	(1.2)	2.5	(0.7)	2.1	(0.6)	9.5	(5.7)
Bromus spp.	5.5	(1.9)	4.1	(0.9)	6.6	(1.8)	4.9	(1.9)
Shrubs								
Atriplex spp.	0.4	(0.4)	0.6	(0.2)	0.3	(0.3)	12.2	(11.0)

Annual diet composition consisted of 76.19% (SE = 1.83%) forbs, 14.58% (SE = 0.95%) grasses, 6.10% (SE = 0.98%) shrubs, and 3.13% (SE = 0.26%) other forage items (seeds, lichens and unidentified flowers). Annual composition of forage available for pronghorn consumption on the CPNM consisted of 35.46% (16.43% SE) forbs and 64.54% (16.43% SE) grasses. Shrubs were not detected within vegetation transects. In comparison to pronghorn occupying grassland, shrubsteppe and desert biomes, pronghorn on the CPNM appeared to have consumed a comparable amount of grasses, but a greater percentage of forbs and a fewer percentage of shrubs (Table 9). Preference ratings, a function of forage use (i.e., diet) in relation to availability (Yoakum 2004c), for forbs (2.2) and grasses (0.2) were similar between the CPNM and grassland and shrubsteppe biomes (Table 9).

Table 9. Comparison between annual available forage composition, diet composition, and preference ratings by forage class (i.e., forb, grass, shrub) for pronghorn on the Carrizo Plain National Monument, CA during 2008 and 2009, and pronghorn occupying shrubsteppe, grassland, and desert biomes (modified from Yoakum 2004c.).

	Carrizo Plain N.M			Grassland biome			Shrubsteppe biome			Desert biome		
	F[a]	G	S	F	G	S	F	G	S	F	G	S
Available forage composition (%)	35	65	-	16	74	9	15	37	46	-	-	-
Pronghorn diet composition (%)	76	15	6	62	19	17	30	7	62	58	2	38
Preference Rating	2.2	0.2	-	3.9	0.2	1.9	2.0	0.2	1.3	-	-	-

[a] F = Forbs; G = Grasses; S = Shrubs.

Seasonal diet composition of forage classes (i.e., forb, grass, and shrub) was consistent throughout the year (Table 11). During all seasons, forbs made up the majority of pronghorn diet, followed by grasses and then by shrubs. In contrast, forage availability varied among seasons (Table 11). During spring, available forb composition (54.40%; SE = 3.29%) was greater than available grass composition (45.60%; SE = (3.29%). However, available forb composition during summer (27.01%; SE = 5.94%) and winter (24.98%; SE = 11.56%) were nearly one-third of available grass composition during summer (72.99%; SE = 5.94%) and winter (75.02%; SE = 11.56%). The seasonal preference rating for forbs was higher during summer (2.78) and winter (2.95) than during spring (1.31). For grasses, the seasonal preference rating was highest during spring (0.36) and lower during summer (0.19) and winter (0.23).

Table 11. Comparison between percent available forage composition, percent pronghorn diet composition and preference ratings of forage classes on the Carrizo Plain National Monument, CA during 2008 and 2009. Percent composition of available forage was calculated using dry biomass weight collected seasonally along vegetation transects. Transect surveys were not conducted during fall and shrubs were not detected within transects. Preference rating is a function of forage use (i.e., diet) in relation to availability. Percent composition of diet was determined by microhistological analysis of pronghorn fecal samples.

Season	Forage class	Available forage composition (SE)	Pronghorn diet composition (SE)	Preference Rating
Spring (Feb – Apr)	*Forb*	54.40 (3.29)	71.07 (6.12)	1.31
	Grass	45.60 (3.29)	16.53 (2.50)	0.36
	Shrub		8.07 (2.43)	
Summer (May – Jul)	*Forb*	27.01 (5.94)	75.02 (2.97)	2.78
	Grass	72.99 (5.94)	13.67 (1.71)	0.19
	Shrub		7.68 (3.25)	
Fall (Aug – Sep)	*Forb*		81.62 (3.06)	
	Grass		12.53 (2.51)	
	Shrub		3.25 (1.72)	
Winter (Nov – Jan)	*Forb*	24.98 (11.56)	73.63 (12.64)	2.95
	Grass	75.02 (11.56)	16.90 (7.24)	0.23
	Shrub		6.70 (6.43)	

Monthly diet composition (Fig. 13) was highest for forbs, followed by grasses and then by shrubs. Consumption of other miscellaneous forage items (i.e., seeds, lichens and unidentified flowers) did not exceeded 10% of the diet for any month. Forb consumption generally increased during the year (from January to December), while monthly consumption of grasses and shrubs declined.

Seasonal vegetative cover of forbs and grasses (Table 12) was highest during spring (25.89%; SE = 0.87% and 43.45%; SE = 1.12%, respectively). Forb and Grass cover declined during summer (19.52%; SE = 0.89 and 29.18%; SE = 1.13, respectively) and again during winter (17.24%; SE = 0.85 and 21.90%; SE = 1.01, respectively). The rate of decline between seasons was higher for grass cover than forb cover. From spring to summer and from summer to winter, grass cover declined by 33% and 25%, respectively; and forb cover declined by 25% and 12%, respectively. The percentage of exposed bare ground (i.e., without vegetation) was < 50% for Summer and Winter (Table 12).
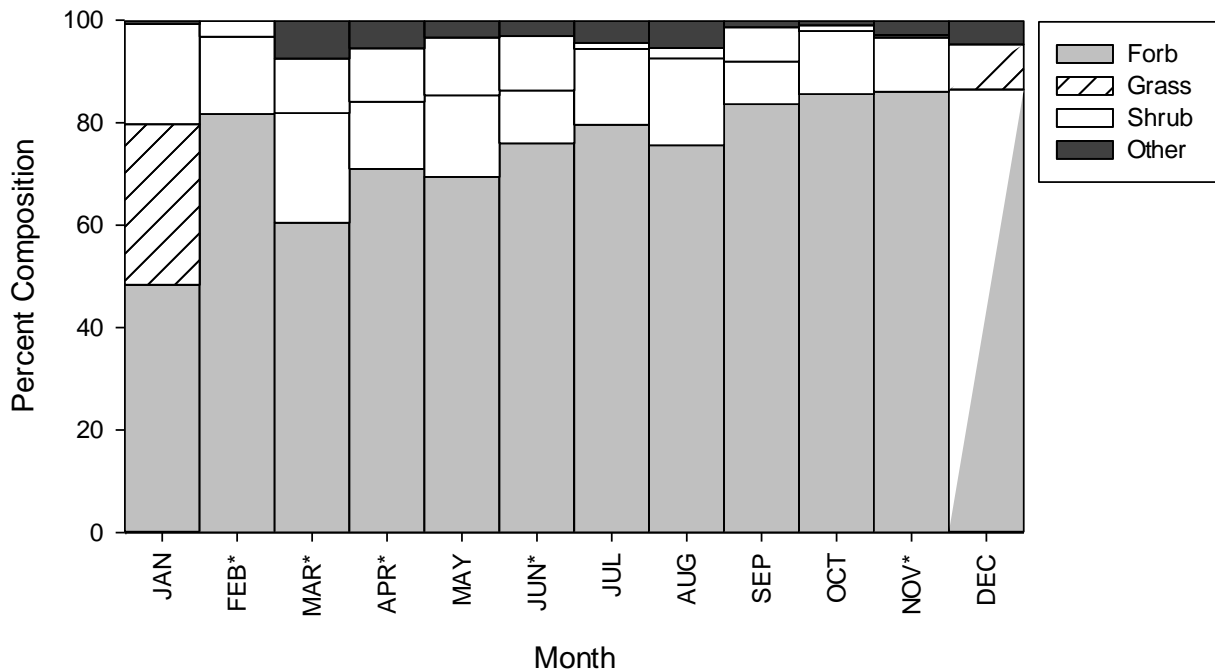
Figure 13. Mean monthly percent composition of forage classes (i.e., forb, grass, shrub) consumed by pronghorn on the Carrizo Plain National Monument, CA during 2008 and 2009. The category labeled "Other" was comprised of seeds, lichens, and unidentified flowers. Diet composition was determined by microhistological analysis of pronghorn fecal samples. Percentages reflect the mean monthly composition for two years except for months for which only one year of information was available (*).

Table 12. Percent forb cover, grass cover and bare ground during spring, summer, and winter on the Carrizo Plain National Monument, CA from 2008 to 2011. The standard error is shown in parentheses. Shrubs were not detected within vegetation transects.

Season	Forb cover	Grass cover	Bare ground
Spring (Feb – Apr)	25.89 (0.87)	43.45 (1.12)	30.66 (1.07)
Summer (May – Jul)	19.52 (0.89)	29.18 (1.13)	51.30 (1.26)
Winter (Nov – Jan)	17.24 (0.85)	21.90 (1.01)	60.87 (1.27)
Mean	20.88 (2.59)	31.51 (6.33)	47.61 (8.91)

We analyzed nutritional composition of available grasses and forbs at peak biomass production during the fawning season to establish baseline data for available nutrients. Comparison of the nutritional quality of grasses and forbs during spring (Table 13) indicated that grasses contained more gross energy (4426.20 calories/gram; SE = 35.04 calories/gram) than forbs (4259.77 calories/gram; SE = 23.80 calories/gram). Additionally, grasses contained a higher percentage of neutral detergent fiber (58.95%; SE = 1.73%) and acid detergent fiber (29.37%; SE = 1.77 %) than forbs (38.82%; SE = 1.47% and 27.24%; SE = 1.00%, respectively). However, forbs contained a higher percentage of crude fat (2.89%; SE = 0.27) and acid detergent lignin (5.19%;

SE = 0.28%) than grasses (1.84%; SE = 0.12% and 1.89%; SE = 0.08%, respectively). Monthly fecal nitrogen (FN) values (Fig. 14a) were highest in March 2009 (3.06%) and April 2008 (3.09%) and lowest during January 2008 (2.01%), January 2009 (2.33%) and August 2009 (2.29%). Monthly fecal diaminopimelic acid (FDAPA) values (Fig. 14b) ranged from a high of 1.15 mg/g during March 2009 to a low of 0.27 mg/g during January of 2008.

Mean preformed water content of available forbs and grasses was 33.1% (SE = 0.01%). Although preformed water content was similar between forbs (38.0%; SE = 0.01%) and grasses (30.3%; SE = 0.01%), seasonal preformed water content was variable. Winter had the highest preformed water content (51.7%; SE = 0.01%), followed by spring (42.8%; SE = 0.01%). Summer preformed water content was considerably lower (5.58%; SE = 0.01%). Preformed water content between foraged plant species (45.58%; SE = 3.11) and non-foraged plant speicies (51.69%; SE = 3.82) did not differ (z = 0.30, p = 0.77).

Table 13. Nutritional information for forbs, grasses, and forbs and grasses combined (in the proportion they were available) on the Carrizo Plain National Monument, CA during spring 2008 and 2009. Forb and grass composition at the time of collection was 67.81% (SE = 1.75%) and 31.97% (SE = 1.74%), respectively. Standard error values are indicated within parentheses.

| Nutritional information	Forbs (SE)	Grasses (SE)	Forbs and Grasses (SE)
% CP Crude protein	9.05 (0.57)	11.31 (1.69)	8.21 (0.35)
Gross energy (calories/gram)	4259.77 (35.04)	4426.20 (58.99)	4275.33 (23.80)
Total ash (grams)	12.44 (0.74)	8.16 (0.67)	9.62 (0.43)
% Crude fat	2.89 (0.27)	1.84 (0.12)	2.37 (0.12)
% Neutral detergent fiber	38.82 (1.47)	58.95 (1.73)	50.56 (1.78)
% Acid detergent fiber	27.24 (1.00)	29.37 (1.77)	30.94 (0.80)
% Acid detergent lignin	5.19 (0.28)	1.89 (0.08)	3.89 (0.23)
% Acid insoluble ash	1.55 (0.40)	0.53 (0.07)	0.58 (0.10)
% In-vitro dry matter digestibility	63.41 (2.04)	47.74 (3.14)	54.05 (2.13)

A

B
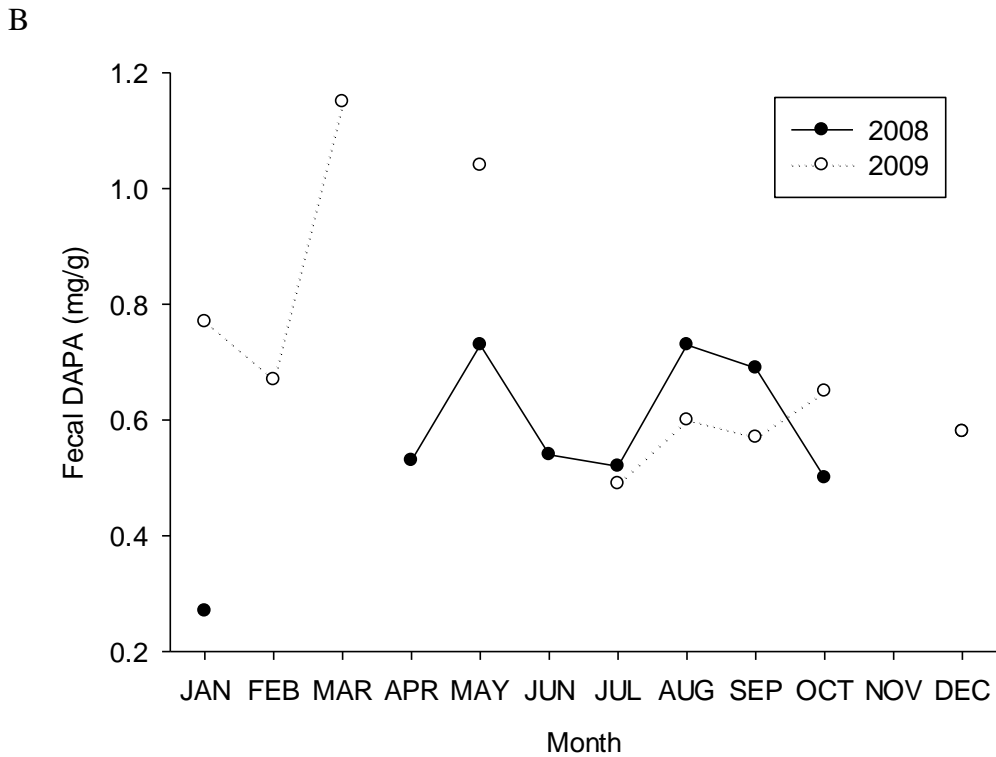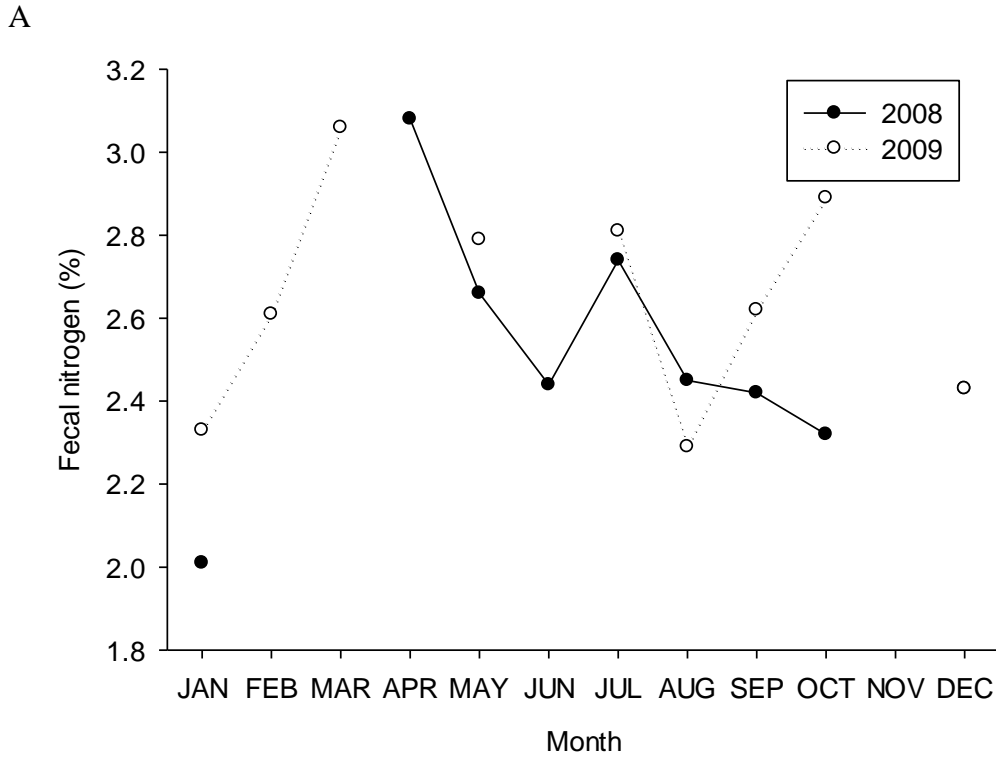
Figure 14. Fecal nitrogen (A) and fecal diaminopimelic acid (FDAPA) (B) measurements for pronghorn on the Carrizo Plain National Monument, CA during 2008 (closed circles) and 2009 (open circles). Information for certain months was not available due to inaccessible road conditions following heavy rains or when no fecal samples could be found.

Discussion

Quantify pronghorn fawn survival

Mean percent survival of pronghorn fawns on the CPNM did not differ from mean percent survival reported for other populations across the species' range (O'Gara and Shaw 2004). It is important to consider, however, that for small populations, seemingly adequate percent survival can only produce limited raw numbers of recruited individuals. During this study, the total number of fawns which survived during any one year was considerably low (between 3 and 5 fawns). In addition, offspring productivity and percent survival varied substantially between years. Although pronghorn commonly exhibit high variability in annual recruitment (Vriend and Barrett 1978, Kohlmann 2004), small or sparse populations are likely to become vulnerable to environmental and demographic stochasticity (e.g., drought and chance variation of births/deaths, respectively) (Courchamp et al. 2008b). Increased rates of fawn survival are likely required to sustain a viable pronghorn population on the CPNM and management actions which increase recruitment will reduce the risk of localized extinction.

Quantify fawn mortality due to predation and other mortality factors.

The primary causes of mortality typically attributed to deceased pronghorn fawns include predation, starvation, exposure and disease (O'Gara and Shaw 2004). Of these mortality factors specifically, we found evidence for predation only. Mortalities related to health appeared to be separate and unrelated events. Predation on the CPNM (29%) was substantially lower than for other populations (53%; O'Gara and Shaw 2004). Although predation is not generally considered to drive pronghorn population dynamics, the importance of predation increases for static or declining populations; as well as for populations occupying marginal habitats or areas where the number of predators is high in relation to the number of pronghorn (Lee et al. 1998, O'Gara and Shaw 2004). In addition, the abundance of alternate prey species (e.g., lagomorphs, rodents, etc.) can alleviate pronghorn fawn predation (Beale 1986). For the CPNM, population density estimates of predators and alternative prey species would be useful to provide an indication of how predator-prey relationships function at this site; and how interspecific interactions may affect fawn survival and predation.

Information for the direct causes of individual mortalities was absent for the majority of deceased individuals. Weak or non-existent VHF signals on collars delayed and/or impeded our ability to recover carcasses and conduct effective necropsies. Often, fawns were consumed entirely before our arrival and/or only small tooth or bone fragments remained. Scavengers (e.g., vultures, corvids, coyotes, etc.) are common on the CPNM and differentiating between scavenging and predation events becomes increasingly difficult with delayed recovery times (e.g., > 48 hours). To investigate the potential for additional predator related deaths to have occurred, we examined patterns in movement in relation to age-specific mortality. Byers (1997b) found that predation is highest for fawns between 11 and 20 days of age, suggesting that the transition from hiding to cursorial (i.e., running) behavior causes fawns to become increasingly visible to predators while still vulnerable to attack. Our results support Byers (1997b) and provide evidence that mortality is associated with increased movement patterns during development. Of the 10 mortalities which occurred during ages of increased fawn movement, the cause of death was reported as unknown for 8 individuals. We consider it likely that predation was involved for a portion of these undetermined cases. Long-term information on fawn

survival and causes of mortality is likely required to accurately assess the importance of predation in driving recruitment and ultimately population size on the CPNM.

Determine the effect of birth synchrony on fawn survival and test for Allee effects.
Examination of our data indicates that birth synchrony was important for fawn survival. All recruited individuals in the study were born during the highest periods of offspring productivity (i.e., *peak periods*) within their respective annual birth distributions. In contrast, the total number of offspring produced each year did not affect survival. Therefore, it appears that the timing and clustering of birth dates (i.e., birth synchrony) was more important than the raw number of fawns produced. However, it is likely that birth synchrony and total offspring production are working together to influence fawn survival. Synchronous birth distributions were detected for the two years of highest offspring productivity and largest population size, suggesting that birth synchrony is density dependent and may degrade in reduced populations. Decreased recruitment rates due to a loss of birth synchrony in reduced populations would produce an Allee effect. Increased population size is likely to create a more synchronous birth distribution and therefore increase offspring survival. Additionally, variables which influence timing and breeding are likely to be important for maintaining synchronous birth distributions. Gregg et al. (2001) suggested that excessive disturbance of adults during breeding season may disrupt social breeding structure (Copeland 1980), which could reduce birth synchrony by lengthening the breeding period. Gregg et al. (2001) also suggested that female nutrition and body condition during breeding and pregnancy are important for maintaining normal estrous cycles and gestation periods; and that birth synchrony may be promoted through management practices which enhance summer and fall forage quality and abundance, or include supplemental feeding during breeding season (Lee et al. 1998).

Our results for the relationship between population size and population growth rate of both the CPNM and CV herds combined indicate that pronghorn across the Carrizo Plain exhibit negative density dependence. Independently however, significant negative density dependence was present for the CV herd only. On the CPNM, density dependency was not observed. Models of demographic Allee effects are often characterized as fitting a "humped shaped" distribution (Courchamp et al. 2008b), where the decline in population growth rate increases with reduced population size (Fig. 2). The CPNM population may be approaching positive density dependence (i.e., Allee effect) as population size continues to decline. Pronghorn on the CPNM are a translocated population and the best test for the presence of Allee effect would be to compare population density and growth rates between the CPNM population and the original population (Modoc plateau, northeast California) (Gascoigne and Lipcius 2004). Evidence from this study suggests that current pronghorn numbers on the CPNM, in the absence of negative density dependence, will remain static.

Evaluate the relationship between fawn survival and habitat.
The fawn habitat selection model indicates that both pronghorn does and their fawns selected for a combination of environmental parameters at both macro and microhabitat scales. Fawn locations had taller vegetation and lower visibility at close distances, but were located within open, highly visible areas. Fawns on the CPNM appear to be restricted to isolated patches of cover within larger areas containing limited concealment from predators. Movement between sparsely dispersed patches of cover is likely to increase risk of detection by predators. However,

pronghorn does may require higher visibility in areas surrounding hidden fawns in order to detect predators. Does with fawns exhibit increased vigilance and aggressive defensive behavior against predators (Byers 1997a) and fawn survival can be higher in habitat containing open areas with shorter vegetation height (Bodie 1979, Autenrieth 1982). Model results also show that forb cover was higher at 100 meters from fawn locations and may indicate that fawns are simply selecting bed sites within areas which also meet the dietary needs of does.

At the macrohabitat scale, fawn locations were in areas with lower slope and within closer proximity to water sources and saltbush shrub communities. Flat terrain increases the ability for adult pronghorn to detect and avoid predators; and the availability of open drinking water for adult pronghorn (fawns acquire water from nursing) can be important in arid environments (Yoakum 2001). Ockenfels et al. (1992) suggested that water on arid grasslands may be an important, if not critical, factor in determining the location of fawn bedsites (Yoakum 2004b). We did not anticipate that proximity to saltbush would be an important habitat variable because saltbush communities on the CPNM tend to be clustered in dense stands with heights that are indicative of low quality habitat (> 50 cm; Longshore and Lowrey 2008). Although moderate dispersal of shrubs in grassland habitats can increase fawn survival (Autenrieth 1982), sites with taller shrub height (76 to 137 centimeters [30 – 54 in]) can have significantly higher predator related mortality (Bodie 1979). If pronghorn on the CPNM are selecting for saltbush based on the need for concealment, then predation risk due to tall shrub height may be increased.

Results from our fawn survival model indicate that locations of individuals which lived beyond 17 days of age were closer to water sources, farther from high-use main roads (i.e., Soda Lake Rd, Selby Rd, Panorama Rd, and Elkhorn Rd.) and on steeper terrain. Model results also indicated that these individuals were located in closer proximity to fences and all roads (small dirt roads as well as main roads), however this association is most likely due to the fact that fences and dirt roads are abundant and well dispersed throughout the monument; not because they increased survival times. The positive association between survival and distance from high-use main roads may indicate that anthropogenic disturbance during the fawning season could influence survival. Proximity to water sources appeared to increase survival times of fawns on the CPNM. Although postnatal fawns acquire water strictly from nursing, and does typically meet most of their water requirements through the consumption of succulent forage items, pronghorn on the CPNM may require supplemental water sources for drinking. The availability and dispersal open water sources on arid ranges directly affects adult health and reproduction, as well as fawn productivity and survival (L. McKee and Wolf 1963, Beale and Smith 1970, Whisler 1984, Ockenfels et al. 1992). We did not expect that survival would be positively influenced by steeper terrain because pronghorn typically select habitat with the lowest slope (Ockenfels et al. 1994). However, Einarsen (1948) found that the best physiography for fawning sites was among basins surrounded by low ridges or hills. On the CPNM, environmental conditions in areas with steeper terrain, including vegetation structure, forage quality and availability, or even the absence of human disturbance, may offer benefits which increase fawn survival and outweigh the costs of increased slope.

We expected that fawning birth sites would be located in traditional fawning areas (i.e., areas where fawns were observed during years prior to the study) (Longshore and Lowrey 2008), however annual birth sites varied between years and were spatially dispersed throughout the

monument; located along both the east and west sides, as well as on the north and south ends of the plain. Selection of traditional fawning areas is dependent on pronghorn seasonal rangeland use (Yoakum 2004b). Herds that are required to travel long distances between summer and winter rangelands due to harsh winter conditions tend to have high site-specific fidelity for traditional fawning locations. In contrast, herds occupying ranges with mild winter conditions, such as on the CPNM, are not forced to travel far between seasonal rangelands and tend to fawn throughout their small home ranges (Yoakum 2004b).

Assess the effects of precipitation and temperature on fawn survival.
Trend information for the correlative effects of climate on offspring productivity and survival are difficult to evaluate for short-term studies. Our data suggests that fawn survival was influenced by low seasonal precipitation and high summer temperatures. Adverse weather conditions on pronghorn ranges, including droughts and severe winters, reduce the availability of nutritious forage, increase predation on fawns, and limit survival overall (O'Gara 2004). Over 20 years following the original reintroduction efforts on the CPNM, mean annual rainfall has been within the range required to sustain a moderately high density pronghorn population (20.3 - 38.1 cm; 8 - 15 in; Yoakum 2004b). However, both annual and seasonal rainfall on the CPNM have been highly variable, creating stochastic environment in which small populations are likely to suffer, especially during sustained drought or temperature extremes. Two years of exceptionally high rainfall in 1998 and 2010 were separated by nearly eleven consecutive years of below mean precipitation. Although pronghorn population size fluctuated over that period, marked population decline appears to have started in 2009, following the decade-long drought. Additionally, habitat quality at this cite has been significantly altered by over one hundred years of dry-land wheat farming and domestic livestock grazing, as well as by inundation of non-native annual grasses (Longshore and Lowrey 2009). Native perennial plant communities provide important forage opportunities for pronghorn during dry summer months, however non-native annual plants become desiccated and vegetative cover is greatly reduced. While mean annual precipitation may be adequate to support a viable pronghorn population on the CPNM, offspring survival and population density are likely limited by poor seasonal forage conditions during summer and fall.

Monitor food habits and nutritional quality of pronghorn diets for evaluation of the effect of diet and forage quality on fawn recruitment.
The abundance, diversity and quality of forage available to, and consumed by, pronghorn directly influence fitness and population density (Yoakum 2004c). On the CPNM, total vegetative cover was within the range typically found on arid rangelands (40% to 60%; Yoakum 1972, Ockenfels et al. 1994). However, the composition of vegetative cover reflected characteristics found in both high and low quality habitats according to criteria developed by Longshore and Lowrey (2009) and modified from Allen et al. (1984), O'Gara and Yoakum (1992), Okenfels et al. (1996), and Yoakum (2004c). Forb and grass cover were representative of high quality grassland-scrub habitat. Shrubs however, were scarce and undetected within our vegetation transects; and shrub cover was indicative of low quality grassland-scrub habitat. This information is consistent with other reports for the CPNM, including Koch and Yoakum (2002) who also reported zero shrub cover within transects and Longshore and Lowrey (2008) who reported low shrub cover and diversity. Habitat with greater forb and grass cover, and relatively lesser shrub cover, is considered optimal for foraging and predator avoidance (Yoakum 2004b). However, the importance of shrubs increases during summer and fall, when late season annual

forbs and grasses are not available (O'Gara and Yoakum 1992). While the amount of forage available to pronghorn on the CPNM may be adequate during late gestation and early postnatal development (i.e., during spring), low forage availability during summer and fall likely affect fawn survival and adult reproduction. Increased shrub cover on the CPNM would likely offer a critical nutrient source for pronghorn during summer and fall, and may be required to increase offspring production and survival, as well as population density.

In comparison to pronghorn occupying grassland, shrubsteppe and desert biomes, pronghorn on the CPNM consumed large amounts of forbs, moderate amounts of grasses, and low amounts of shrubs. Regardless of habitat type, forbs comprise the majority of pronghorn diet and shrub composition is generally equal to, or far greater than, grass composition. Grasses are consumed increasingly, however, where shrubs are not plentiful (Yoakum 2004c). On the CPNM, shrub consumption was atypical and comprised less than half the composition of grasses. Pronghorn are highly selective foragers, and although forage availability may vary among different habitats, the preference for certain forage classes is remarkably consistent (Yoakum 2004c). This was supported by our results, where preference ratings for forage classes on the CPNM were the same as other populations. The strong preference for certain forage classes across habitat types indicates that pronghorn are highly restricted by forage availability on rangelands, especially during certain times of year. Pronghorn can make seasonal adjustments to their diet according to nutrient availability associated with plant phenology. Forbs are most nutritious during spring and summer, and consumption of forbs during these periods has been linked to offspring production and survival (Yoakum 2004c). Shrubs have comparatively high nutrient levels in fall and winter and can be important for adult body condition during breeding and pregnancy (Yoakum 2004c). Maternal condition during late gestation can affect offspring birth weights (Thorne et al. 1976) and low birth weight can decrease survival (Thorne et al. 1976, Clutton-Brock et al. 1982, Fairbanks 1993). Grasses can offer important digestible energy during winter. On the CPNM however, pronghorn did not appear to adjust their diet to account for seasonal changes in forage availability. Even when late season forbs and grasses were largely desiccated and vegetative cover was greatly reduced, pronghorn on the CPNM continued to consume forage classes in the same proportion throughout the year. Pronghorn occupying arid lands, such as the CPNM, can exhibit less pronounced shifts in seasonal diet (Cancino 1994c, Miranda 2000) compared to pronghorn in northern grassland and shrubsteppe habitat (Salwasser 1980, Yoakum 1990). Although shrub availability was not well measured, the relatively high consumption of grasses and the low consumption of shrubs throughout the year, indicate that shrub availability is likely limited on the CPNM. Limited availability of preferred forage items during different seasons is likely to have a negative influence on individual fitness and restrict population growth on the CPNM.

Plant taxa in pronghorn diets during this study were similar to results from 2003-2004 for shrubs and grasses (Longshore and Lowrey 2008). However, the number of forb species in the diets during this study was lower than in 2003-2004. Pronghorn did consume other miscellaneous forage items including seeds, lichens and unidentified flowers, however mean percent composition of these items was small ($< 3.5\%$) and their relative importance in the diet is likely insignificant.

Nutrient quality of pronghorn diets can be evaluated by measuring fecal nitrogen (FN) and fecal diaminopimelic acid (FDAPA) content (Leslie and Starkey 1987). On the CPNM, FN values were highest during March and April and lowest during January and August; and FDAPA values were highest during March and lowest during January. Although seasonal differences in percent FN and percent FDAPA were not statistically significant, and some variability occurred between years, seasonal trends overall matched those found for other pronghorn populations (Hansen et al. 2001).

Pronghorn often make use of preformed water (i.e., water contained in forage) because surface water typically occurs sparsely in most pronghorn habitats (Sundstrom 1968, Boyle and Alldredge 1984, Kindschy et al. 1982). When moisture content in plants exceeds 75%, pronghorn may cease drinking, even if surface water is readily available (Beale and Smith 1970). On the CPNM, preformed water content was low and pronghorn were frequently observed making use of water sources. Seasonally, preformed water content was particularly low during summer and was likely lower during fall. The abundance of forage with high moisture content during spring and summer can influence fawn survival (Beale and Smith 1966) and moisture content during fall likely influences adult body condition. Studies indicate that plants foraged by pronghorn have higher moisture content than non-foraged plants (Fox 1997, Beale and Smith 1970, Deblinger and Alldredge 1991, Hughes 1991) and selection of plant species with higher preformed water content can be important for offspring production and survival (Yoakum 2004c). On the CPNM, no difference was detected between preformed water content of foraged and non-foraged plant species. In certain arid environments preformed water content alone may not be enough to support viable populations, especially during particularly dry seasons (Fox 1997). Water on arid grasslands may be an important factor influencing fawn bedsites (Ockenfels et al. 1992) and will likely continue to be critical for pronghorn on the CPNM.

Discussion Summary
Results from this study indicate that, under current biotic and abiotic conditions on the CPNM, increased pronghorn population density is not likely to occur without management strategies which enhance fawn productivity and survival. Additional translocations of adult pronghorn may augment population size temporarily by promoting birth synchrony and decreasing potential Allee effects, as well as by reducing the overall risk associated with environmental and demographic stochasticity. However, habitat conditions within the CPNM indicate low carrying capacity for pronghorn and future translocations are not likely to succeed without prior rangeland manipulation.

Management Recommendations
Vegetation
Fawning areas should be considered critical habitats (Lee et al. 1998) and manipulation of vegetation height, structure and availability surrounding traditional fawning areas may increase pronghorn productivity, fawn survival, and overall population density on the CPNM. It should be noted, however, that specific distribution of fawning areas may vary annually because sites can be more closely associated with vegetative cover than with geographic locations (Autenrieth 1984). Vegetation treatments can include the use of fire, biological controls, mechanical and chemical treatments and artificial seedings. Treatments can be used individually or in

combination with one another, and the decision for which treatment to use is based on the specific problematic characteristic (*see* Yoakum 2004d). For the CPNM, it appears that increased shrub cover, diversity, and moderate spatial dispersal are needed to improve concealment of fawns from predators and to provide important late-season nutrients during adult breeding and reproduction. Presently, available shrubs on the CPNM tend to be dominated by large, dense saltbush (*Atriplex* spp.) stands which may reduce visibility of predators and offer limited seasonal nutrition. Pronghorn prefer a mosaic of vegetative structure rather than extensive monotypic plant communities and mechanical or chemical treatments are the preferred method for reducing the density of large shrub stands (Yoakum 2004d).

Forb and grass cover on the CPNM appear adequate, particularly during spring. However, most of the forbs and grasses on the CPNM are annual plants, and management practices which promote perennial plant growth are likely to increase the quality and availability of nutrients and preformed water content during summer and fall. Prescribed fires are an economical and practical treatment method and post-fire seeding with a mixture of grasses, forbs and shrubs (six species per each forage class) were recommended by Yoakum (2004d).

Birth synchrony appeared to be important for fawn survival and management practices which influence timing and breeding may be important for maintaining synchronous birth distributions. Enhanced forage conditions during breeding and pregnancy can be important for maintaining estrous cycles and proper timing of birth.

Water
Our results indicated that open water sources were important for fawning habitat and survival. Rangelands with year-round drinking water every 1.6 to 3.2 kilometers produce more pronghorn than areas with fewer water sources; and drinking water can be increasingly important for pronghorn in habitats with variable precipitation and low forage succulence (Yoakum 2004b). Rainfall and the availability of preformed water (water contained in forage) on the CPNM are low during summer and fall. Maintenance of current water sources could be critical for pronghorn on the CPNM, especially during dry seasons or periods of sustained drought. Testing water sources for potential toxins, levels of total dissolved solids and pH (pronghorn avoid water containing >5,000 mg/L dissolved solids and with pH exceeding 9.25; Sundstrom 1968) are recommended.

Predation
Although predation affects fawn recruitment on the CPNM, rates of predation do not appear to be excessive. Predators on the CPNM are generalist and do not rely on pronghorn fawns as a critical prey source. Therefore the presence of alternative prey species which predators consistently rely on are likely important to reduce predation on pronghorn fawns. Comprehensive population density estimates for predators, as well as alternative prey species, would provide a valuable resource for land managers to evaluate the potential for predation to limit fawn recruitment.

Acknowledgements

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Appendix A. Information for fourteen pronghorn fawns collared on the Carrizo Plain National Monument, CA from 2009-2011.

Fawn ID	819-2009	581-2009	944-2009	531-2009	644-2009	756-2009	881-2009	694-2009	700-2009	200-2009	668-2009	800-2009	831-2009	694-2010	881-2010	581-2010	756-2010	881-2011	531-2011	756-2011
VHF frequency	165.819	165.581	165.944	165.531	165.644	165.756	165.881	165.694	165.700	165.200	165.668	165.800	165.831	165.694	165.881	165.581	165.756	165.881	165.531	165.756
Sex	Male	Male	Male	Female	Female	Female	Male	Female	Female	Male	Female	Female	Male	Female	Male	Female	Female	Female	Female	Female
Date of birth	04/26/2009	05/01/2009	05/01/2009	05/01/2009	05/01/2009	05/05/2009	05/05/2009	05/06/2009	05/06/2009	05/13/2009	05/25/2009	05/25/2009	05/24/2009	04/28/2010	04/28/2010	05/02/2010	05/10/2010	04/27/2011	04/04/2011	05/05/2011
Survived?	Yes	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No	No
Age at death (days)	-	17	16	36	-	17	7	36	3	3	21	21	16	12	15	18	-	-	13	9
Date of capture	04/30/2009	05/01/2009	05/01/2009	05/01/2009	05/01/2009	05/07/2009	05/08/2009	05/09/2009	05/09/2009	05/16/2009	05/25/2009	05/25/2009	05/26/2009	04/28/2010	04/29/2010	05/05/2010	05/12/2010	05/01/2011	05/08/2011	05/08/2011
Age at capture (days)	4.00	0.17	0.17	0.17	0.17	2.00	4.00	3.00	3.00	3.00	1.00	1.00	1.00	0.29	1.50	3.00	3.00	4.00	4.00	3.00
Easting (UTM)	261800	270875	270875	247996	247996	243885	248263	271470	271283	261370	244041	244041	239786	243821	243192	249250	241904	244001	248797	249031
Northing (UTM)	3882550	3876121	3876121	3887517	3887517	3890498	3887650	3874555	3874506	3882888	3895175	3895175	3893748	3895700	3894522	3897080	3897286	3894944	3892872	3892909
Start time	1900	1205	1205	1700	1700	1655	1152	1135	1325	1204	1906	1906	1408	1600	1105	1730	1500	1407	1400	1830
End time	1915	1220	1220	1720	1720	1715	1215	1159	1349	1225	1944	1944	1425	1630	1130	1745	1520	1425	1430	1845

processing time (minutes)	15	15	15	20	20	60	63	24	24	21	38	38	17	30	25	15	20	18	30	15
Weight (kg)	-	4.20	4.10	4.20	4.10	4.00	4.50	3.75	3.60	4.05	3.50	3.50	3.70	3.95	4.00	4.10	4.00	4.10	4.40	3.95
Body length (cm)	-	-	-	-	-	58.0	63.0	60.7	62.0	67.7	59.4	59.6	53.1	59.8	61.0	62.0	61.0	63.5	61.5	60.9
Tarsus length (cm)	-	-	-	-	-	50.5	22.0	21.2	20.4	20.8	20.5	21.0	21.2	20.9	20.4	21.2	22.3	21.0	21.6	20.5
Neck girth (cm)	-	-	-	-	-	19.0	18.0	17.5	17.0	17.9	18.3	17.7	16.5	17.8	18.7	16.5	17.4	18.2	17.5	17.0
Body girth (cm)	-	-	-	-	-	-	38.0	38.7	37.3	41.7	37.5	37.3	36.5	38.0	38.0	39.1	39.4	39.1	38.0	37.5
Body temperature (Fahrenheit)	-	-	-	-	-	103.2	102.6	104.9	103.8	106.8	103.0	102.7	109.4	102.4	102.9	104.0	105.4	104.8	105.7	104.2
Number of incisors	-	-	-	-	-	2	4	4	6	4	2	2	4	2	2	4	2	2	8	6
Blood sample collected?	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
# of vials taken (lavendar, red/black, blue)	0,0,0	0,0,0	0,0,0	0,0,0	0,0,0	1,1,1	1,2,1	1,1,1	1,2,1	0,0,1	1,1,1	1,1,1	1,1,1	1,0,1	1,0,1	1,1,1	1,0,1	1,1,1	0,0,0	1,1,1

Missing information was either not applicable or not collected during capture.

Appendix B. Laboratory necropsy results for two pronghorn fawns from the Carrizo Plain National Monument, CA in 2010 and 2011.

California Animal Health & Food Safety Laboratory System

105 W. Central Avenue
San Bernardino, CA
92408-2113

Final
Version 1
This report supersedes all previous reports for this case

CAHFS Case #: S1003930
Referral #: PRONGHORN
Date Collected: 05/14/2010
Date Received: 05/14/2010
Case Coordinator: F.A. Uzal, DVM, MSc, PhD, Dipl ACVP
Electronically Signed and Authorized By: Uzal, Francisco A. on 6/23/2010 1:25:04PM

Email To:
CALIF DEPT OF FISH AND GAME
pswift@dfg.ca.gov

Specimens Received: 1 Carcass;

Case Contacts		
Bill To	CALIF DEPT OF FISH AND GAME	916-358-1462 BIO TST VAR/WL P08800011701 NIMBUS ROAD SUITE D RANCHO CORDOVA, CA 95670
Report To	BLAIR, S	
Submitter	GONZALES, BEN JOE	916-358-2790 1701 NIMBUS RD STE D RANCHO CORDOVA, CA 95670

Specimen Details				
ID	ID Type	Taxonomy	Gender	Age
	CAHFS Internal ID	Pronghorn Antelope	Female	

Laboratory Findings/Diagnosis

Prognhorn, history of acute disease and death:

1-Internal umbilical remnant infection (omphalophlebitis), suppurative, with myriad intralesional coccobacilli, with extension to the liver; etiology Fusobacterium necrophorum, Bibersteinia trehalosi

2-Hepatitis, necrotizing-suppurative, multifocal to coalescing, with myriad intralesional coccobacilli; etiology Fusobacterium necrophorum, Bacteroides sp. and B. trehalosi

Other lab test results
1-No parasite eggs detected in feces
2-Negative Yersinia culture
3-Negative Brucella culture
4-Bluetongue PCR, Negative; spleen.
5-BVDV PCR, Negative; spleen.

Case Summary

5/16/10: This animal had a severe umbilical infection which was the portal of entry for the liver infection. Although I think it is unlikely the case, I have ordered cultures for plague and tularemia, in addition to regular bacterial cultures. All the other tests requested will be performed as soon as these two diseases are ruled out. I will keep you posted with our results, but in the meantime, please do not hesitate to contact me if you would like to discuss any aspects of this report.

5/19/10: Histology confirmed a diagnosis of necro-suppurative hepatitis. Cultures are still pending. Please keep in mind that the Yersinia spp. culture may take up to 4 weeks before this microorganism can be ruled out.

06/18/10 (Dr. Diab on behalf of Dr. Uzal): Fusobacterium necrophorum was isolated from the liver lesions. Bluetongue and BVD PCR were negative and Yersinia sp were not isolated. Additional bacteriology to follow.

6/23/10: Several bacterial organisms were isolated from the umbilicus and liver. This concludes testing in this case.

California Animal Health & Food Safety Laboratory System

105 W. Central Avenue
San Bernardino, CA 92408-2113
(909) 383-4287

Final
Version 1
This report supersedes all previous reports for this case

CAHFS Case #: S1103780
Referral #: PRONGHORN FAWN
Date Collected: 05/04/2011
Date Received: 05/05/2011
Case Coordinator: Alfonso De la Mora
Electronically Signed and Authorized By: De la Mora, Alfonso on 6/3/2011 3:46:15PM

Email To:
GONZALES, BEN
boonzale@dfo.ca.gov

Collection Site:
San Luis Obispo

Specimens Received: 1 Carcass;

Comments: Hand: Chris

Case Contacts

Bill To	CALIF DEPT OF FISH AND GAME	916-358-1462	BIO TST VAR/WL P08800011701 NIMBUS ROAD SUITE D RANCHO CORDOVA, CA 95670
Owner	LOWREY, CHRIS	702-564-4537	160 N STEPHANIE ST HENDERSON, NV 89079
Submitter	GONZALES, BEN	530-754-8245	WILDLIFE INVESTIGATIONS LABCA DEPT OF FISH AND GAME RANCHO CORDOVA, CA 95670

Specimen Details

ID	ID Type	Taxonomy	Gender	Age
	CAHFS Internal ID	Pronghorn Antelope		1.50 Days

Laboratory Findings/Diagnosis

A newborn, male Pronghorn fawn with history of being found dead.

Gross findings:
Acute internal bleeding with:
1. Abdominal cavity: Hemoabdomen, acute, severe.
2. Liver, right lobe: Hepatomegaly with focal hepatic laceration, multiple subserosal hemorrhages, acute, moderate, and diffuse congestion.

Other results.
* No Leptospira-like organisms detected on kidney smear by FA.
* Rare mixed bacterial flora isolated from the liver, lung and brain (most likely post-mortem contaminants).

Case Summary

5-06-11: The cause of death of this fawn was hemorrhagic shock due to severe blood loss, most likely from trauma to the liver. There were no obvious external gross lesions suggestive of trauma on the skin such as bruising or puncture wounds, and no fractures of ribs and vertebral column. No tears were noted in the abdominal aorta and its branches. The lungs were inflated and sections floated in formalin suggesting that the fawn was not stillborn. Histology of various tissues is pending and may provide more information regarding the gross findings.
Results on histology and bacteriology will be forwarded when they become available, in the meantime, if you have any questions regarding this report, please do not hesitate to contact me.

6-2-11: Histology of liver confirmed that the tear observed on necropsy was an ante mortem event. This change was most likely the cause of bleeding and death of this fawn. Isolation of rare numbers of mixed bacteria flora from liver, lung and brain is more likely due to a postmortem contamination and is of no clinical significance for this case. Changes in kidney are unspecific and may indicate an early change of autolysis. Absence of hypoxic changes such as cell swelling and necrosis indicate that this animal's death was acute.

All testing is now been completed.

Appendix C. Percentages of forage items in the diet of pronghorn on the Carrizo Plain National Monument, CA in 2008 and 2009. Percentages are based on microhistological analysis of fecal samples.

| | Forage item | 2008 | | | | | | | | | 2009 | | | | | | | | Mean annual |
		JAN	APR	MAY	JUN	JUL	AUG	SEP	OCT	DEC	JAN	FEB	MAR	MAY	JUL	AUG	SEP	OCT	
FORBS	*Astragalus* spp.	4.0	2.0	1.2	4.9	5.5	2.1	3.4	3.9	11.5	11.6	24.5	9.6	3.7	10.5	6.8	9.1	7.1	7.1
	Camissonia spp.	4.0	5.1	11.8	18.0	14.7	6.5	10.7	13.0	11.3	2.0	6.3	1.8	1.9	4.8	2.7	3.5	4.6	7.2
	Chenopodium								0.8							0.4			0.6
	Cirsium												1.0						1.0
	Clarkia spp.	0.3	0.3	0.8						0.4						0.6			0.5
	Delphinium spp.															0.4			0.4
	Epilobium spp.	5.9												3.2					4.6
	Erodium spp.	11.5	22.2	17.8	13.8	22.1	23.9	5.4	23.6	27.5	25.0	18.9	21.7	17.8	30.6	20.8	27.4	30.0	21.2
	Eriogonum spp.		0.6	3.1							1.5			1.2			0.5		1.4
	Euphorbia (Chamaesyce) spp.		0.9																0.9
	Gilia spp.										0.7	0.5		0.7			0.2	0.2	0.5
	Lactuca serriola		2.9																2.9
	Lepidium spp.	2.3	4.5	4.1	4.2	1.1	1.0	0.3	2.5	1.6	2.2	0.5	0.2	0.6	0.9	0.6	0.5	4.0	1.8
	Lomatium												1.4			0.8			1.1
	Lotus spp.	0.1	6.5	2.5	3.1	9.5	6.3	1.9	4.8	9.7	5.6	8.9	0.8	1.9	2.4	6.6	11.1	9.5	5.4
	Lupinus spp.		0.6	2.7	0.9	2.1	0.6	0.1	3.1	0.8	0.4	4.4	5.5	5.6	1.4	6.6	6.4	2.2	2.7
	Mentzelia spp.		0.3																0.3
	Monarda	3.1	4.9							5.5	2.5	2.3	1.3	1.5			0.9		2.8
	Phacelia spp.		2.2	1.5	0.5	5.0	8.2	1.8	1.7	1.6	0.4	0.9	1.3	6.2	2.9	2.3	0.4	5.7	2.7
	Phlox/Linanthus									2.0	1.1	0.5		1.5			0.9		1.2
	Plantago spp.		2.2	1.5		1.5					1.8	0.5	5.5	3.5	1.1	0.2			2.0
	Salsola tragus				0.5	1.1	2.5	4.2								2.7			2.2
	Salvia spp.		0.3						1.0	1.6							0.9		1.0
	Trifolium spp.			0.2			0.4	0.3		0.2		0.7		0.7		0.4	0.2	0.2	0.4

	Aster family flower		5.1	7.9	20.7	9.4	14.7	41.7	7.7	5.9	4.4	1.9	1.3	2.7				0.8	9.6
	Aster (Composite) family hair		3.1	2.7	0.9						0.7	0.9		2.1	0.3	0.2	1.3	2.0	1.4
	Borage family		2.1	2.7	0.9	12.6	9.8	2.4	7.0	2.4	1.8	2.3	2.3	14.8	6.0	4.3	5.3	21.4	6.1
	Cruciferae (Mustard family)			0.4	0.4			3.4	0.2	0.2	0.5	0.7	0.3		0.8		0.5	1.8	0.8
	Flower														0.4				0.4
	Lamiaceae (Mint family)		1.8	2.7	0.5		0.4												1.4
	Legume pod		0.6	2.7	3.6		2.1	3.9	5.0	1.6	0.4	2.3			4.1	9.3	10.6	1.2	3.6
	Polygonaceae family												0.6						0.6
	Uknown Forb	1.1	2.8	3.7	3.1	3.1	2.0	3.0	6.2	2.7	1.8	3.3	4.1	2.5	5.1	5.2	5.1		3.4
	Forb Total :	**32.3**	**71.0**	**70.0**	**76.0**	**87.7**	**80.5**	**82.5**	**80.5**	**86.5**	**64.4**	**81.7**	**60.5**	**68.9**	**71.5**	**70.7**	**84.8**	**90.7**	**74.1**
GRASSES	*Avena* spp.	20.2	4.0	1.9	2.7		2.1	3.0	3.7	0.8	7.6	0.5	3.9	5.6	2.5	1.9	0.9	0.8	3.9
	Bromus spp.	6.2	1.8	1.9	4.5	1.5	3.7	2.4	10.3	1.2	7.3	8.0	6.8	7.4	5.7	11.3	3.5	5.3	5.2
	Distichlis spicata		0.9																0.9
	Elymus spp.							0.4											0.4
	Hordeum spp.										5.4		0.3						2.9
	Leymus triticoides	0.6	1.5		0.9			0.6		1.2	0.4	0.5	1.0	4.1	4.8	0.4		1.2	1.4
	Poa spp.	4.0	0.6	0.8	0.9	2.3	3.7		1.7	2.4	4.0	3.3	5.2	1.5	0.6	5.1	1.3		2.5
	Stipa (Nasella) spp.	0.8	4.3	1.5		1.5		1.8		2.4	0.7	0.9	4.2	2.4	4.8	2.3	1.8		2.3
	Vulpia spp.										2.2			1.5					1.9
	Uknown Grass				1.3	2.7			0.8	0.8	3.3	1.9		3.2	3.2	3.5	1.3	0.4	2.0
	Grass Total	**31.8**	**13.1**	**6.1**	**10.3**	**8.0**	**9.5**	**7.8**	**16.9**	**8.8**	**30.9**	**15.1**	**21.4**	**25.7**	**21.6**	**24.5**	**8.8**	**7.7**	**15.8**
SHRUBS	*Artemisia* spp.															0.4			0.4
	Atriplex spp.	34.1		1.2	1.3	0.4	0.4				2.5		1.3			1.6			5.4
	Chrysothamnus nauseosus		0.9	3.9	0.9			0.1	0.6				4.4	0.4				3.3	1.8
	Ericameria	0.6	9.2	7.2	8.0	0.4		5.4											5.1
	Gutierrezia californica	0.6		4.2		0.8		1.8	0.8				4.9	4.4				0.9	2.3

	Isocoma acradenia	0.6		1.2		0.8							1.4						1.0
	Krascheninnikovia lanata		0.3		0.4														0.4
	Quercus spp.												0.9			0.4			0.7
	Shrub stem							0.9			0.7		0.9			1.2	0.9	0.8	0.9
	Shrub Total	**35.9**	**10.4**	**17.7**	**10.6**	**2.4**	**0.4**	**8.2**	**1.4**	**0.0**	**3.2**	**3.2**	**10.6**	**4.8**	**0.0**	**3.6**	**5.1**	**0.8**	**7.0**
OTHER	Seed		5.5	6.2	3.1	1.9	9.6	1.5	1.2	4.7	1.5				6.0	1.2	1.3	0.8	3.4
	Flower												1.3						1.3
	Lichen												6.2	0.6	0.9				2.6
	Other Total	**0.0**	**5.5**	**6.2**	**3.1**	**1.9**	**9.6**	**1.5**	**1.2**	**4.7**	**1.5**	**0.0**	**7.5**	**0.6**	**6.9**	**1.2**	**1.3**	**0.8**	**3.1**
	Grand Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**