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Grappling with Wild Pigs in California High Country: Wild Pig Population and Disturbance Research at Tejon Ranch

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ABSTRACT: Wild pigs cause extensive damage to ecological resources, agricultural lands, and private property, and carry diseases that may pose a health risk to livestock and humans. At the Tejon Ranch in the Tehachapi Mountains of California, a population of wild pigs produce extensive ecological and economic damages, and share rangelands with cattle. Via the Tejon Ranch Conservation and Land Use Agreement, the Tejon Ranch Conservancy is charged with the science-based stewardship of over 970 km^2 of conserved lands at Tejon Ranch. During the summer of 2014 we initiated pilot field research to develop monitoring and control methodologies to better manage wild pigs and associated disturbance across Tejon Ranch's conserved lands. We compared line transect surveys (LTS) with remotely triggered wildlife trap-cameras as alternative methods to estimate pig abundance. Density estimates were made from LTS survey results using program DISTANCE, while indices of abundance were developed from camera trap data. We also estimated ecological disturbance by measuring the amount of pig rooting along segments of LTS transects. Wetland areas, along with higher elevation interior habitats received more damage than dryer, lower elevation habitats, which was expected given our summer surveys. Expanding on these pilot abundance surveys, we are now attempting to achieve more precise population density estimates using mark-resight techniques through a combination of trapping and collaring animals as well as individually identifying pigs from their unique pelage patterns.

KEY WORDS: abundance estimation, damage estimation, DISTANCE sampling, mark-resight, population, *Sus scrofa*, wild pigs

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INTRODUCTION

Located just 70 miles north of downtown Los Angeles, the 1,093-km^2 privately owned Tejon Ranch is the primary open space corridor connecting the Angeles and Los Padres National Forests with the Sequoia National Forest and the southern Sierra Nevada. The Ranch, located in the western Tehachapi Mountains, is uniquely positioned at the confluence of four of California's major bioregions, where the Mojave Desert meets the Coast Ranges, Sierra Nevada, and the Great Central Valley. Consequently, Tejon Ranch boasts remarkable biodiversity, including numerous threatened and endangered species such as the California condor (*Gymnogyps californianus*), San Joaquin kit fox (*Vulpes macrotis mutica*), and the striped adobe lily (*Fritillaria striata*). Regrettably, the Ranch also supports a significant population of invasive wild pigs (*Sus scrofa*) that cause extensive ecological, agricultural, and property damages.

As a popular game species, wild pigs have often been intentionally introduced to foreign landscapes, dramatically expanding their range throughout much of the world. In the early 1990s, a private landowner neighboring Tejon Ranch brought in wild pigs for hunting. The pigs subsequently escaped and began expanding into the neighboring wildlands. A quarter-century later this population has ballooned into the thousands – more than one in four pigs reported harvested in California come from Tejon Ranch (CDFW 2013) – mirroring the typical pattern of wild pig infestations across much of the U.S. Despite high harvest rates, hunting pressure alone appears to be inadequate as a population control measure (Dzieciolowski et al. 1992, Saunders 1993, Caley and Ottley 1995), and as pig populations continue to expand throughout the United States, so too does the disturbance associated with their rooting, wallowing, and foraging across our native ecosystems (The Wildlife Society 2011).

In 2008, a land use agreement between the Tejon Ranch Company and five of California's leading environmental conservation organizations placed 90% of Tejon Ranch, some 971 km^2, under permanent conservation, and established the Tejon Ranch Conservancy as an independent land trust responsible for its stewardship. Developing and implementing science-based stewardship to protect, enhance, and restore the conservation values of Tejon Ranch is central to Conservancy's overall mission. A major research and management focus of this mission is the mitigation and control of disturbance to native ecology produced by invasive wild pigs across the Ranch's conserved lands.

METHODS

Our initial wild pig research and management efforts focused on developing techniques to measure pig abundance on the Ranch and the disturbance they cause across different habitat types. While the extensive damage and disturbance caused by wild pigs across the Americas is well-documented (The Wildlife Society 2011), many fundamental aspects of their ecology are still largely unknown. Data on range size, expansion potential, survival rates, and fecundity have been limited, particularly in

California and the southwestern U.S. Sweitzer and colleagues (2000) estimated statewide wild pig densities for California from 0.7 to 3.8 pigs/km^2, which would extrapolate to a Tejon Ranch-wide population of between 764 and 4,150 individuals. In early 2014, we set out to improve our general understanding of pigs on Tejon, in particular their density and abundance, as well as the distribution of rooting and wallowing damages they cause, with the hopes of informing effective population management and disturbance control measures on Tejon Ranch and elsewhere.

2014 Surveys

To estimate population density and abundance, we began by conducting line transect surveys (LTS) using a DISTANCE sampling approach (Thomas et al. 2010). We established a 400-km^2 survey grid covering all the primary habitat types at Tejon Ranch. The grid was composed of 100 2-km^2 cells, based on preliminary indications of average range size (Sweitzer et al. 2000). Within each cell, a randomized 4-km-long transect arranged into a 1 × 1-km square oriented along cardinal directions was established. Transects were surveyed during the 2-hour window between one hour before and after sunrise or sunset, when wild pigs were most active at Tejon. All observed wildlife and their perpendicular distance from the transect line were recorded. Density was estimated using Program DISTANCE (Thomas et al. 2010).

We also used motion-activated wildlife trap-cameras to estimate an index of pig abundance. Along each 4-km LTS, one camera was fixed to a tree or t-post to record wildlife activity on a game trail, wallow, or other high activity area. Except for occasional interference from cattle and wildlife, the trap-cameras recorded 30-second videos over 30 consecutive nights following the observational LTS. Each "encounter" of wild pigs at a camera was recorded and the pigs present in each encounter were categorized demographically (adult male, adult female, unknown adult, juvenile, piglet). Encounters were either a single video or multiple consecutive videos that were separated from a subsequent encounter by an hour "quiet period" (a period of inactivity). An index of abundance expressed as number of pigs per camera-night was developed for each camera position.

In addition to estimating abundance, ecological disturbance associated with wild pigs was estimated through a viewshed survey. At each of the four corners of the 4-km DISTANCE LTS square, we estimated the percent of the 360° viewshed at that location that was visibly disturbed by wild pigs. The total viewshed area and the type of habitat disturbed was also recorded.

Survey Modifications for Summer 2014

Leading into summer of 2014, experience gleaned early in the year led to modifications in study techniques. As is commonly the case in preliminary field surveys, our wild pig population survey protocols encountered unforeseen complications when faced with the many technical and practical challenges of field data collection in remote wilderness. The success of our pilot LTS was negatively impacted by the steep terrain and dense vegetation characteristic of Tejon Ranch. This steep topography and dense vegetation made walking 4-km surveys on a fixed bearing frequently impossible, and even where straight-line transect surveys were navigable, survey pace was highly variable due to habitat type and terrain. Our ability to observe wildlife was significantly inhibited by the noise created by attempting to survey fixed transects through dense vegetation. Similarly, our ability to detect disturbance in a given viewshed proved to be heavily biased towards more open habitat and vegetation types.

To address these limitations, we modified our surveys to allow the surveyor the flexibility to move around obstacles and sections of inaccessible terrain to achieve a relatively uniform survey pace approximating 1.5 km/hr. Survey distance was measured by GPS-tracking to assure equivalent survey length in a general direction regardless of elevation changes and obstacles. This consistent pace combined with the ability move around dense vegetation also afforded us the best opportunity to remain quiet and make wildlife observations regardless of habitat type. The resulting orientation of the 4-km transect was no longer a regular square, but rather an irregular 4-km transect standardized by survey time and total distance.

Disturbance estimations required more substantial revision, as viewshed estimates proved to be imprecise and impossible to make in closed or densely vegetated landscapes. We adopted a line-intercept transect survey approach. In each grid we conducted eight, 25-m line-intercept disturbance surveys at 500-m intervals along each 4-km LTS. Along each 25-m line-intercept transect, rooting and wallowing along the line was recorded and categorized by severity and age. Severity was categorized by the depth of the rooting or wallowing, with severe disturbance reaching or surpassing the level of the upper soil horizon. Age of disturbance was assessed by the presence of any regenerating vegetative growth out of the rooted or otherwise disturbed soil. Where new growth was present, disturbance was classified as "old." Disturbance that could not be definitively attributed to wild pigs – e.g., certain wallows or heavily used cattle and game trails – were recorded separately as "unidentified" and were excluded from our preliminary disturbance analyses.

RESULTS

From April through July 2014, 42 LTS using the DISTANCE sampling approach were conducted across the 200-km^2 survey area using the revised protocols. During these LTS one or more pigs were observed in 27 of 42 grids surveyed. From these data Program DISTANCE generated a mean density estimate of 0.069 pigs/ha, with a 95% confidence interval of 0.034-0.139 pigs/ha. This extrapolates to a population estimate of 680-2,780 individuals across the survey area, and 1,400-5,600 individuals across the entire Ranch, assuming the entire was area was occupied.

From March through August 2014, wild pig activity was captured on 61 wildlife cameras. Cameras documented an average 1.68 individuals/camera-night (range of 0-15.78 individuals/night), with a 95% confidence interval of 1.00-2.36. The cameras documented an average of 0.58 pig encounters/camera-night, with the average encounter consisting of 2.25 individuals (standard deviation = 2.34). There were 25 survey cameras that detected pigs in grid cells in which no pig observations were made through

LTS. Conversely, of the 27 cells where pigs were observed via LTS, only three cameras associated with those grid cells failed to detect pigs.

Disturbance transects were conducted along each of the 42 LTS following the summer 2014 protocol revision (Table 1). Disturbance was quantified as a proportion of the overall line-intercept transect length and differentiated by the eight primary habitat types characterizing the study area. On average, approximately 15% of the areas surveyed appeared disturbed, with significantly higher disturbance in the higher elevation, interior mixed hardwood conifer, and oak woodland habitat types.

Table 1. Pig-related disturbance by habitat type.

Habitat type	Average Proportion Disturbed	Standard Error
Desert scrub	0.07	0.04
Grassland	0.07	0.03
Mixed conifer	0.27	0.04
Mixed conifer/oak woodland	0.21	0.02
Mixed conifer/riparian	0.24	0.02
San Joaquin Valley oak woodland	0.20	0.05
Antelope Valley oak woodland	0.16	0.02
Oak woodland/ riparian	0.20	0.05

DISCUSSION

Wild pig densities generated from our surveys – albeit with wide confidence intervals – are higher than those previously estimated for California (Sweitzer et al. 2000). This is consistent with other indications that Tejon Ranch supports a large population of wild pigs, particularly the productivity of the Tejon Ranch Company's pig hunting program, one of the largest in California. The Tejon Ranch Company's hunt program harvested over 1,000 pigs in 2013 and over 1,200 in 2014, and although annual hunter harvest rates may fluctuate for many reasons other than population density, it does suggest a Ranch-wide population well into the thousands of individuals, which is consistent with our preliminary estimates.

The evolution of our wild pig survey methodologies in 2014 yielded valuable insights to improve study protocols. Preliminary analyses of our LTS data indicate that DISTANCE sampling surveys are hypothetically viable under certain conditions. To be viable, surveyors should be provided the flexibility to maneuver through terrain and vegetation features when operating in challenging landscapes in order to maximize the probability of detecting pigs. Additionally, survey effort should be proportionately scaled to the area being investigated. A single surveyor operating across our 200-km^2 survey area produced a limited sample size that contributed to the wide confidence window associated with our LTS density estimates. This diminished the power of the DISTANCE survey approach, revealing a weakness in this method for estimating density over such a large and complex study area. The steep and densely vegetated terrain of Tejon Ranch also restricted the ability of the surveyor to detect pigs and slowed the survey pace, further diminishing the overall efficiency of the observational LTS approach.

We also found that the effectiveness of the DISTANCE sampling approach at Tejon was diminished by the active pig hunting program taking place throughout the study area. Wild pigs have been shown to actively avoid detection in areas where they are hunted (Barrett and Birmingham 1994), and during our DISTANCE surveys wild pigs were most often detected at greater distances from the survey transect, indicating that pigs closer to the observer were likely fleeing before detection. Additionally, we found that detection is also affected by terrain and vegetation characteristics that vary dramatically across the survey grid. These factors likely conspire to violate the assumptions of DISTANCE sampling and thus bias any resulting density estimates.

Overall, trap-cameras proved to be more reliable than observational LTS as a method of estimating population abundance. Camera index results are more consistent compared with LTS observations across similar habitat types and geographic regions. However, without identifiable individuals in the population to be incorporated into mark-resight models, only indexes of abundance can be derived from trap-camera data alone.

Results from our surveys suggest pigs are significantly disturbing many habitats. We observed disturbance to be greatest at higher elevations and in more interior areas of the Ranch where perennial water persists through the summer. These surveys were conducted during the dry season, when lower elevation habitats across the Ranch are generally more inhospitable to wildlife activity of any kind. The year 2014 was the third consecutive year of drought in our region of California, which only exacerbated these arid conditions. This likely contributed to a reduction in disturbance in the dryer, lower elevation areas of the Ranch. We anecdotally observed that the seasonality of disturbance appears related to soil moisture, as wetter soils were more often rooted than drier soils.

Both our trap-camera index and disturbance surveys highlighted the importance of consistency and continuity across time. Trap cameras, when appropriately distributed across a study area, are a powerful tool for assessing where wildlife occur. They are inconspicuous and require minimal maintenance to be productive, which is particularly useful in remote areas or when surveying animals that avoid humans. However, in order to achieve their full potential as a survey tool, multiple cameras must be evenly distributed across a survey area and run concurrently for extended periods. Similarly, for disturbance surveys to accurately assess the vulnerability of certain habitats to wild pig disturbance, they must account for the way that wild pig disturbance impacts different habitat types, and how those habitats recover from disturbance over time. For this reason surveys of disturbance should be distributed evenly across the study area's various habitats and administered routinely over an extended period of time.

Moving Forward

The Conservancy is continuing to expand our wild pig research through a partnership with the USDA's Animal and Plant Health Inspection Service (APHIS) and their National Feral Swine Management Program. As part of this federal initiative to address growing concerns over invasive wild pigs throughout the United States, Tejon Ranch is serving as a representative West Coast study site for multi-year research to develop efficient methods for estimating wild pig population density, growth trends, spatial use patterns, and demography. These estimates will help us understand current population and habitat use trends and how the associated risks of ecologic and economic damages are likely to change over time, to help bolster our development of effective population control and risk management strategies for use on Tejon Ranch and throughout the U.S.

The resources and expertise brought to the partnership by the USDA have substantially enhanced our research by initiating a program of trapping and collaring animals with identifiable marks and GPS-tracking technology, an endeavor that previously had been prohibitively costly for the Conservancy. Mark-resight population estimates derived from resightings of collared and tagged individuals in remotely triggered wildlife cameras, allows an estimate of density using camera technology rather than surveyor observations, presumably a more efficient and powerful tool in a landscape such as Tejon Ranch. This technique also allows the Conservancy to compare mark-resight population estimates derived using natural pelage patterns to identify individual pigs at Tejon with those from the artificially marked pigs.

These surveys are still ongoing, but already meaningful insights can be gleaned from this effort. Trapping pigs for collaring, while invaluable for research, is an extremely costly and time consuming endeavor. The capture mark-resight approach to density estimation is useful only as long as a significant proportion of the overall population is identifiable; this requires a significant effort to deploy enough marks in a large population of animals. Identifying individuals from pelage patterns and scars has been used successfully to estimate populations in other species (Cooke et al. 2008), and requires significantly less resources to obtain a comparable proportion of "marked" animals in the populations. Our preliminary estimates indicate that approximately 15-20% of pigs at Tejon Ranch can be individually identified by natural marks alone. Our next step is to directly compare the results of these two approaches.

The Conservancy has also further refined our approach to monitor wild pig disturbance across different habitat types. Four permanent 2-m-wide by 100-m-long belt transects were established in each of the four primary habitat types represented in the study area (grassland, mixed hardwood-conifer, open oak woodland, and closed oak woodland). These transects are being surveyed seasonally, and disturbance along each transect is mapped, photographed, and recorded to be compared against future surveys. As new surveys are conducted, current conditions along the transect belt can be compared against previous survey results to see how different habitat types recover from disturbance over time as well as the rate at which new disturbance is occurring. In addition, disturbance surveys arebeing conducted around a sample of water resource types that are available across the study area, which includeriparian corridors, unprotected springs, and springs protected by cattle-proof and pig-proof fencing.

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