Feral Pig Management on Tejon Ranch, CA

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Executive Summary

Tejon Ranch is located approximately 60 miles north of Los Angeles and encompasses 270,000 acres of native grasslands, pine forests, and oak and Joshua tree woodlands. The ranch represents some of the most spectacular and ecologically important wildlands in California. A 2008 landmark conservation agreement between the ranch's owner, the Tejon Ranch Company (TRC), and several leading conservation and environmental groups, permanently protected 240,000 acres from development. The conservation agreement created the Tejon Ranch Conservancy, which is responsible for protecting and managing the open space on the ranch.

Located squarely in the heartland of southern California, the ranch is perhaps best known for the wildflowers that blanket its hills and valleys in the springtime, but it is also home to a host of other wildlife, including herds of antelope and elk as well as several iconic endangered animals like the California condor. Somewhat less iconic are the herds of pigs that were accidently released on the ranch in the late 1980s from a neighboring pig farm. This original population became feral and has multiplied and spread. The larger population of pigs has directly impacted the quality of Tejon's ecosystem, regularly rooting up the soil and leaving muddy pools in addition to eating numerous species of bulbs, roots, plants, and animals. The destructive population is not expected to decline without intervention; under optimal conditions, pig populations have the potential to triple every year as mature sows typically birth 2 litters of 5 to 6 piglets each year (Barrett 1978).

TRC currently operates a feral pig hunting program on the ranch, but there is no other active management of feral pig populations. This project will research and analyze the effectiveness of hunting as a control mechanism for feral pig populations, and it will examine other management options available to the Conservancy. In order to know which management options are viable for the Conservancy's feral pig populations, the project will conduct an extensive literature review and identify useful indices of feral swine abundances, spatial distribution and ecological impacts within a given study area. Knowledge gleaned from these indices will be key to the future feral pig management goals of the Conservancy.

The project will then make recommendations to the Conservancy for potential feral pig management plans based on the ability of each strategy to provide the greatest value in terms of efficacy, ecological and economic benefit, and stakeholder interest. We will accomplish this using a multi-criteria analysis that incorporates cost-benefit analysis and non-monetary risk analysis, including stakeholder acceptability and legal barriers analysis. Ultimately, the product of the analysis will be utilized not only for management decisions on Tejon Ranch but also will serve as a model for analysis in other parts of California with the potential to provide policy makers with the tools and information to determine the best approach for feral pig management statewide.

Objectives

In this project, we will answer the following questions:

1. Assessment of pig abundances, spatial distribution, and ecological and economic effects:
What are relevant indices of feral pig abundances and spatial distribution for feral pigs on Tejon Ranch? What are the types and magnitudes of ecological effects (positive and negative) associated with feral pigs in semi-arid ecosystems, and what are relevant indices for assessing ecological effects? What are the economic and societal impacts of feral pigs in California and Tejon Ranch specifically? What are the regulatory, policy, and land use contexts of feral pig management in California in general and specifically at Tejon Ranch?

2. Management options:
What feral pig management techniques are available to the Tejon Ranch Conservancy? What have their practicality, cost, and efficacy been in other relevant settings? How do these various management techniques fit within California's regulatory, policy, and land use context, and what constraints (social, economic, or practical) exist for feral pig management at Tejon Ranch? What are the relevant trade-offs (effectiveness vs. cost vs. political feasibility vs. acceptability by stakeholders)?

Significance

Managing feral pigs is an issue throughout most of the U.S. and almost all of California. Feral pigs are found in 56 of California's 58 counties. The population in California is estimated to be between 200,000 and 400,000, and the total U.S. feral pig population is estimated to be over 5 million (J. Mayer and L. Brisbin, 2009). The range of feral pigs both across California and the greater U.S. appears to be increasing as well. Preliminary results from analysis of pig harvest (R. Sweitzer, UC Berkeley, unpublished data) show that pigs extended their range in California by more than 7,000 square miles between 1992 and 2004. Rough estimates based on literature and local hunting guide knowledge put the feral pig population between 1,000-4,000 individuals on the property. It is believed that the pig populations are spread throughout the entirety of Tejon Ranch.

Feral pigs can be highly destructive animals. Underground bulbs and insects compose a significant portion of their diet and they root up the soil to access these food sources (Barrett 1978). This feeding behavior, compounded by their abundance throughout California, means that the animals are causing varying degrees of damage to ecosystems across the state. Where high density populations have emerged, they have significantly damaged protected lands and agricultural resources (Sweitzer et al. 2000). Pigs also threaten livestock by competing for food sources and transmitting diseases (Choquenot, McIlroy, & Korn 1996). While disease transmission from pigs has not been documented on Tejon Ranch, the pigs are causing significant, although yet to be quantified, ecological damage. There is also anecdotal evidence that pigs are encroaching on cattle

operations. As such, better management of the population is critical to preserving the fragile ecosystems on the ranch, as well as the various economic interests of the Tejon Ranch Company.

Unlike most other states, California has classified feral pigs as big game species instead of a pest species. The state lacks a comprehensive feral pig management plan, placing other private lands, preserves, and parks around the state at risk as the pigs' range continues to expand. Comprehensive management plans that work within the legal framework of the state are very rare and there is a need for cost effective strategies on private lands and protected public lands (Sweitzer et al 2000). Indices of abundance, spatial distribution, and ecological effects as well as management options developed by this project may be extrapolated and used as a model for controlling feral pigs on public and private lands throughout California and the U.S.

1. Background & Literature Review

The following background information builds on the extensive background and literature review already conducted by Dr. Kyran Kunkel with several key additions.

A. Feral Pig Ecology

i. Habitat and diet

Feral pigs are habitat generalists, meaning that they can survive in most areas of North America by feeding on plants and animals and changing food preference based on availability. Preferable habitats for pigs include oak woodlands, mixed-conifer forests, oak grasslands, and chaparral shrublands (Mayer and Laudenslayer 1988). Feral pigs are omnivores and will consume the eggs of ground-nesting birds, amphibians, and reptiles (Merton 1977, Jolley et al. 2010). Dr. Kunkel noted in his literature review that Bratton (1975) found that species richness of small mammal and herpetofaunal communities was reduced due to habitat deterioration where wild pigs forage (Bratton 1975) . Similarly, Jolley found that a substantial number of herpetofauna are consumed by wild pigs on Fort Benning, Georgia each year and that some species seem to be targeted by pigs (Jolley et al. 2010). At Tejon Ranch specifically, feral pigs pose a threat to forb and bulb plant species, tree seedlings such as oaks, as well as amphibians and other species. In the summer or dry season, pigs are limited by water, shade availability, and food sources.

ii. Population dynamics

Pigs are very prolific large mammals (TWS 2011). Under adequate environmental conditions, female sows can reach reproductive capability while still juveniles and are capable of reproducing twice a year. Litters of more than 10 are possible although sizes of 3 to 8 are more likely (Barrett 1978). Because of these traits and the lack of many natural predators, there is potential for high population growth given the right environmental conditions. Sows typically travel in groups with other sows and young, while boars tend to be solitary. Based on the minimum convex polygon method, home range size of wild pigs in California ranged from 2.3 -7.5 km^2, with an average of 2.5 km2 (Sweitzer et al. 2000). Density estimates for wild pigs in California ranged from 0.7 – 3.8 pigs/km^2 (Sweitzer et al. 2000). The average lifespan of a feral pig is between 4-5 years.

iii. Predation

Common feral pig predators found in California include black bears (*Ursus americanus*), mountain lions (*Puma concolor*), coyotes (*Canis latrans*), and bobcats (*Lynx rufus*). All of these species inhabit Tejon Ranch, although their effects on pig populations are unknown. Studies have shown that mountain lions appear to consume more pigs in the wet season than the dry (Hopkins 1989). At Tejon, pig carcasses also serve as an important food source to scavenging animals such as the California condor.

B. Negative Ecological and Economic Effects of Feral Pigs

i. On wetlands and riparian zones

Tejon Ranch contains numerous fragile wetland systems, and the literature suggests that the feral pig populations are causing significant damage to sensitive ecosystems such as these. It has been documented that feral hogs can have detrimental impacts on both local water quality and aquatic biota (Kaller et al. 2007). In California's Pinnacles National Monument (PNM) there was great concern over the degree to which feral pigs negatively impacted limited wetland areas, which are a vital resource for native wildlife. Impacted species included the threatened California red-legged frog (*Rana aurora*) and California tiger salamander (*Ambystoma californiense*; National Park Service [NPS] 2003, McCann and Garcelon 2008). In a Louisiana study, dense pig populations were associated with decreased water quality, particularly in the form of increased fecal coliforms (Kaller et al. 2007).

Pigs cause economic damage in wetlands and riparian zones, especially in areas that have been actively restored (where large amounts of time and money have been spent), from their rooting, trampling, and wallowing. Although it is difficult to measure the value of wetlands in economic terms, authors of the 2012 feral pig management plan for New York used the public's "willingness to pay" (i.e., the amount of money people are willing to spend to restore different types of wetlands) in order to place a monetary value on acres of wetlands damaged by feral swine (New York Feral Swine Management Report 2012). Using methods similar to Engeman et al. (2007), the Wildlife Service in NY estimated the monetary value of their wetlands based on a report to the EPA in 1997 for the northeastern U.S. (King 1998). Because it was not known which freshwater wetland type in New York received the most damage from feral pigs, the lowest "willingness to pay" value per acre was used, which was for the emergent wetlands type. After adjusting for inflation (BLS 2012), a conservative estimate of the value of restoring wetlands lost to feral pig damage in New York was approximately $62,970.10 per acre. Using the Environmental Protection Agency's estimate of 1 feral swine destroying 10 acres of wetland in its lifetime, the 40 individuals that the Wildlife Service culled from the NY population in 2012 represented a potential $25,188,040 worth of damage to wetlands in the state (New York Feral Swine Management Report 2012).

ii. On terrestrial ecological communities

The deeper feral hogs root into the ground, the more plant roots or rhizomes are exposed to the atmosphere, leading to reduced plant growth and increased plant mortality (Bratton 1975). Exposed roots also make the plant vulnerable to mortality, either from exposure or because of subsequent herbivory by hogs or other animals upon those exposed roots. In addition, feral hog uprooting of debris and leaf litter, even at low to moderate intensities, may adversely affect the native ecological processes of the ecosystem (Kastdalen 1982, Lacki and Lancia 1986). Plant debris and leaf litter on the ground surface serve as protective cover for small vertebrates and invertebrates, and the litter and debris also aid in the regeneration and succession of various plant species. Feral pigs may also reduce oak regeneration through consumption of mast (Loggins et al.

2002), and some researchers have found that pigs have facilitated dispersal of nonindigenous plant species throughout the Preserve monument by exposing soil for colonization (Aplet et al 1991, Cushman et al. 2004).

Tierney and Cushman (2008) have shown that native and exotic plants from different functional groups vary greatly in how they recovered from pig disturbances. Exotic taxa were generally able to rapidly colonize and persist in pig disturbances, whereas native taxa usually exhibited a slow but steady rebounding following pig disturbance. They suggested that the health of coastal California grasslands may be enhanced substantially by eliminating or greatly reducing the size of feral pig populations.

iii. On agriculture and viticulture

Tejon Ranch leases small portions of its land for agriculture and viticulture, and also has its own farming operation. As such, feral pigs damage to these operations is a concern for ranch management. In less than a week, a single group of feral pigs can destroy a 10-acre cornfield (Gates 2012). The state of Georgia estimates that feral pigs caused over $57 million in crop and crop related damage within its boundaries in 2011 alone (Mengak 2012). While pigs most commonly damage forage crops in ecosystems like Tejon's, they can also damage pastures (Beach 1993). Damage effects include can wasted fertilizer, tractor, and operator time (Mengak 2012). Such indirect losses from feral pigs can be difficult to measure but are nonetheless important.

Based on crop damages and control costs of about $300 per pig annually, feral pigs are estimated to be causing at least $1.5 billion in damages and control costs nationwide (Pimental, 2007). For California, a survey was conducted in 1998 that investigated all 58 county agricultural commissioners in California and reported $1,731,920 in feral swine damage for the year. This figure was likely underestimated because only 69% of county agricultural commissioners responded, and the exact number and monetary value of damaged resources was conservatively estimated (Frederick 1998).

Grape growers in Texas and California have reported feral pigs damaging vines and uprooting plants (Kane 2010, McCoy 2012). Pig damage to vineyards can occur rapidly. For example, in the Hérault area of southern France, compensation paid to vineyards for damage by wild pigs increased from $31,352 (U.S.) in 1990-1992 to $700,890 in 1993 (Calenge et al. 2004). On Tejon, 6,000 acres are devoted to pistachios, almonds, alfalfa, and wine grapes. In particular, there are more than 1,400 acres devoted to vineyards in two locations, the mountain area and the valley floor.

iv. On ranching

Depending on the time of year, Tejon contracts to allow no more than 14,500 head of cattle on the ranch. Two separate livestock tenants conduct all cattle operations on Tejon. The first runs cattle on

a 55,000-acre lease on the northern portion of the ranch, while a second leases 195,000 acres in the central and southern areas of the ranch.

At least 30 diseases and 37 parasites transmissible to people, domestic animals, and livestock have been documented in feral pigs (Seward et al 2004). Pigs can roam, thus making them effective agents of disease and parasite transmission, and livestock that share water sources with pigs can be particularly vulnerable (Mason et al. 1998, Witmer et al. 2003). The abundance of water troughs on the Tejon property makes this concern particularly relevant for this project.

v. On property

Feral pigs can rapidly destroy sod when rooting for food in locales such as lawns, sports fields, and golf courses. This behavior leads to unsightly, erosive areas. Repairing this type of damage can be expensive. States with growing feral pig populations` are encountering these types of property damage more and more (Higginbotham 2012). This effect may become more relevant as portions of the ranch are developed, particularly the Tejon Mountain Village. It will be important to think about the possibility of the pigs using the developed areas are refuges if hunting pressure or other management techniques are increased elsewhere on the ranch

C. Positive Ecological and Economic Effects of Feral Pigs

i. Ecological benefits

While some speculation exists that feral pigs can provide ecological benefits for some species, we have found no scientific reports to verify this. All of the reports that we have read focus on the heavy damage that pigs cause.

ii. Economic benefits

Tejon's hunting program is a source of revenue for the Tejon Ranch Company. The ranch currently takes about 800 pigs per year via hunts, with a stated goal to take 1200 pigs in the 2013-2014 season. With their Private Lands Wildlife Management License, the Ranch sets the hunting seasons, the harvest limits, ages of animals to be harvested, and the number of hunting licenses issued. Feral pigs are not covered under this program, however.

The Tejon hunting website states that "pigs in excess of 200 pounds are not uncommon" (Tejon Ranch Wildlife Management, 2012). There are several types of pig hunts available at Tejon. There are guided pig weekday hunts ($1100/person) and guided pig weekend hunts ($1200/person). There are also Wild Pig Management Hunts (WPMHs), which are the only non-guided hunt offered at Tejon that does not require a membership. The cost for these hunts is $500 per hunter and is offered on a variety of weekends.

D. Management Options

i. Non-lethal control

These means include sterilization, trapping and relocation of animals, and fencing. Sterilization as well as trapping and relocation can be "complex, labor intensive and not practical" (Sweitzer 2003). As Dr. Kunkel notes in his feral pig literature review, "there are currently no long term methods for feral pig sterilization that do not require field surgery of captured animals to implant hormone release devices. There are shorter term injection hormones being tested, but none currently approved for use in feral pig control (West et al. 2009)" (Kunkel Feral Pig Management Chapter 2013).

Studies have also been conducted examining the usefulness of electric fencing (Reidy et al. 2007). As Dr. Kunkel notes, "combining electric fencing with other damage control methods in an integrated management program may be the best method for alleviating feral pig damages and controlling populations. However, efficacy of electric fencing to protect other economically and ecologically important areas, such as orchards, livestock, and wetland habitats, from feral pig damage needs scientific evaluation" (Kunkel Feral Pig Management Chapter 2013). The efficacy and benefit of fencing pigs out of sensitive areas on Tejon will be analyzed in this project.

ii. Lethal control

There are lethal methods geared towards control or towards eradication of feral pig populations. The most widely accepted methods for control include increasing natural predation, hunting, trapping/snaring, use of trained dogs, and aerial gunning.

a. Increased hunting pressure

Feral pigs are regulated as a game species in California, and hunting of the animals is widespread and popular. Using hunting to control feral pig populations in Australia and New Zealand has shown that it may be necessary to eliminate at least 70% of the population in a given year to reduce or maintain population numbers (Dzieciolowski et al. 1992, Caley and Ottley 1995, Saunders 1993).

Heavy hunting pressure can be a somewhat effective tool in maintaining or reducing population sizes (Pine and Gerdes 1973, Schauss et al. 1990). It is possible, however, that these methods can stimulate population growth by increasing the access to resources for the remaining pigs (Fernandez-Llario et al. 2003, Massolo and Mazzoni della Stella 2006). As Dr. Kunkel notes in his literature review, "although hunting is important for controlling feral hogs, hunting alone cannot eradicate feral hog populations (TWS 2011)." An additional complication is that in response to hunting pressures, pigs can learn to avoid detection, either by becoming more nocturnal or retreating to refuges where hunters either cannot or do not frequent (Barrett and Birmingham 1994). This may become a concern for Tejon Ranch in the development areas where, presumably, hunters will not be allowed.

Furthermore, Toigo et al. (2008) found that harvest focused on adult males and limited hunting pressure on adult females and piglets reduced the effectiveness of hunting to control growth of wild boar populations. They concluded the need to be willing to harvest piglets and females. If the first method of control that the Conservancy is going to explore is increased hunting pressure from the TRC hunting program, this information will need to be communicated to the hunters and hunting guides.

2. Methods for Measuring Feral Pig Abundances, Spatial Distribution, and Ecological Effects

Developing a sound management plan for the feral pig population at Tejon Ranch will require a number of methods to gather sufficient data about feral pig abundances, spatial distribution, and ecological effects in order to advise the Conservancy on potential management options. In order to estimate annual feral pig population trends, we propose to use 3 methods: (1) a passive tracking index (PTI) in conjunction with a pervasiveness index, (2) scat surveys which may lead to DNA analysis in order to develop an actual measure of pig abundance and population characteristics on the ranch, and (3) a hunter/hunting guide survey. In order to estimate pig ecological effects, we will use either a fresh damage index or other damage indices. We hope to link the density indices with damage indices to gauge how population controls affect ecosystem damage. Due to the geographic size of Tejon Ranch, it is necessary to narrow the study size of our project to a reasonable size. Our primary study area will be Tejon Canyon, which contains a good sample of vegetation and climates present throughout the ranch (see appendix D). Secondary sites are yet to be determined for other areas of the ranch.

It is important to note that the Conservancy will be able to use these initial indices of abundances, spatial distribution, and ecological effects that we will develop to compare the effects of increased hunting pressure or other management techniques on feral pig populations on the ranch.

A. Indices of Feral Pig Abundances and Spatial Distribution

i. Passive Tracking Index (PTI) and Pervasiveness Index

One of the most effective ways to generate a useable estimate of feral pig populations is through the development of a PTI. We plan to develop a PTI for specific areas within Tejon Ranch. While population models can be useful for detailed information about local pigs, indices are considered a more useful tool for management purposes (Flemming 2001). Engeman et al. (2001, 2007) found that indices of abundance rather than absolute abundance estimates were the only practical means for monitoring pigs due to the difficulty of actually measuring feral pig density.

Collection of these data have been vital for adapting and optimizing management strategies to achieve maximal impact on hog populations with the resources available. We believe that, given the limited data time available to the group for data collection and the size of Tejon Ranch,

development of a PTI in Tejon Canyon will give TRC and the Conservancy a useful management tool that can be updated and expanded in years to come to suit management needs.

A PTI is a low-tech method that involves placement of tracking plots throughout the area of interest in hog travel routes, such as dirt roads or game paths. At each plot, the number of hog track sets (number of intrusions into the plot) is recorded for 2 consecutive days at each assessment time. After 24 hours, the plots are examined for spoor and resurfaced (tracks erased and surface smoothed) for the next day's observations. The PTIs and associated variances are calculated according to methods developed by Engeman (2005) where a mixed linear model describes the number of intrusions on each plot each day. Adding to the robustness of the index, the variance formula derivation is based on a non-zero covariance structure among plots and among days. That is, without assumptions of independence among plots or days (Engeman 2005).

For most study sites, Engeman et al. (2001) created tracking plots 3-m long that spanned the dirt road or track. We plan to develop a PTI using these general guidelines (3 meter plots and monitoring on consecutive days) with adjustments being made to coincide with Tejon's management needs. Furthermore, maintaining permanent passive tracking plot locations maximizes index comparability over time, providing a useful means to assess the changes in feral pig abundance.

Applications of the tracking plot information and the PTI have included (1) optimizing the timing and strategy for pig removal, (2) minimizing labor by identifying areas where pig removal would have maximal effect, (3) assessing efficacy of removal efforts, and (4) serving as a detection method for reinvasion and identification of directions from which reinvasion occurs.

Prior to beginning summer internships, the Bren team has laid out stratified random plot locations, where we stratify by elevation and vegetation type (appendix E). We then removed areas that are simply inaccessible or impractical by utilizing GIS information. We will verify these transects with input from Drs. Kunkle and White. Following the lead of Wilder Ranch State Park's pig index, we will plan to set up 10 1 km long transects with plots every 100 m (Swolgaard 2002). The Bren team will make this decision, along with Drs. White and Kunkle, at the outset of their summer work. Where feasible, attempts will be made to have plots that are placed directly on established trails and secondary roads as well as in other stratified random locations in order to neither overestimate nor underestimated abundances (Swolgaard 2002). Once the two members of the Bren team arrive at the ranch, they will check the viability of the plots. When the viability is determined to be acceptable, the plots will be established. Visual marks will be used to establish the plots, and their location will be input into a GIS system. The interns will coordinate with the Tejon Conservancy to adopt a schedule for checking the plots that fits in with the PTI's time criteria and ranch wide management activities. Track data will be recorded for consecutive days and put into the index on a weekly basis.

The Bren team will also use the data that is gathered from the plots to establish an index of pervasiveness. The pervasiveness index uses measurements from all of the plots to generate an

estimate of the spatial distribution of the pig population (Engeman 2001). The index of pervasiveness (IP) is defined as IP = $(1/n)\sum(w1/w2)$, where n is the number of plots, w1 is the square of the distance from a tracking plot to the nearest plot with pig tracks (nearest neighbor sample), and w2 is the square of the distance from that nearest plot to its nearest plot with tracks (second-nearest neighbor sample). When a pig track is observed in a plot, the distance to the nearest plot with a track is generated via GIS information, as well as the distance to the second nearest plot with a track. These distances are squared and input into the index. As Engeman et al. (2001) notes, "When the pattern is entirely random, IP = 1. If the plots with tracks show aggregation (localized concentrations), then IP >1. If tracked plots show a systematic pattern, then IP<1. This index could be particularly useful for examining re-invasion patterns by describing the saturation of the area with swine." Developing the pervasiveness index will require no additional data collection from the interns beyond specify which plots have fresh tracks, and it will allow the ranch to establish a baseline for the spatial distribution of the pigs in our study areas.

The interns will process the data that they have gathered at the end of each workweek. Data will be input into the indices and results will be kept in both Excel spreadsheets and GIS. We anticipate having the full data collection in place by the end of the summer. Similarly, the interns will begin to construct the index over the summer and whatever work remains on that portion of the project will be completed during the fall quarter.

Additionally, the use of game cameras to generate accurate, time-stamped data on pig populations can often times reveal population patterns that are not apparent during diurnal observations. In order to generate this data, we plan to work with the Conservancy to purchase cameras and install them at relevant locations near certain transects and PTI plots. By combining cameras and PTI plots, we can "ground-truth" the plots and subsequent indices. By doing so, the Conservancy will be able to put plots in other parts of the ranch, where it is not feasible to continue placing cameras, and compare data collected from those plots with the plot data that the interns this summer will collect. Furthermore, the use of the cameras may render it possible to pick up other important species and individually identify them for capture mark recapture techniques which could be helpful to the Conservancy on future projects.

ii. Scat index with potential for mark-recapture DNA analysis

Scat surveys can be used to estimate the relative abundance of species, including feral pigs (Kunkel et al. 2005). In this method, transects are established and all scat found in them is initially removed. After a certain amount of time, several days for example, the transects are canvassed, and any scat found is collected once again. A scat index is created as "number of scat collected/transect/deposition period (Kunkel et al. 2005). The validity of using scat deposition rates to estimate relative population abundances have been demonstrated by various sources (Knowlton, 1994). If possible, we propose to use transects that allow for simultaneously data collect from the PTI plots discussed above. Furthermore, the collection of scat will facilitate scat DNA analysis if such a method is determined to be feasible (Ebert 2012).

If determined to be feasible, processing of the collected scat will take place as soon as possible. We anticipate conducting some of this work during the Fall quarter to have the data fully processed by the start of the Winter quarter. While we do not plan to develop a full population model, these results will help us begin to build the foundations for such a model that Tejon can then build on in the years to come.

iii. Hunter and hunting guide surveys and data

We will also develop a survey for the hunting guides, hunting clubs, and hunters on Tejon Ranch in order to access their local knowledge about feral pig abundances, spatial distribution, and affected areas on the ranch. This type of survey has been found to be precise in detecting trends in other animal populations and is inexpensive and practical to administer (Kunkel et al. 2005). These surveys can be validated and their bias calibrated by comparing the results of the surveys with the results of the PTI and scat surveys. Then, information gleaned from hunter surveys in areas where there is no PTI or scat survey monitoring can help focus additional PTI and scat survey locations. See appendix A for a draft version of the survey.

Supplemental hunting data that we will gather is pig tag and hunting data from TRC. All hunters who hunt on the Tejon Ranch are required to purchase pig tags through the California Department of Fish and Wildlife and the state tracks hunter successes with these tags. This information can be compiled, along with data gathered through the Tejon Ranch hunting program, to generate a simplistic population estimate (Waithman 1999). More importantly, having the hunters and guides regularly fill out surveys will establish a steady stream of information about pig population on the ranch that can be utilized for future management.

B. Indices of Feral Pig Ecological Effects

i. Fresh damage index

One way to estimate effects of feral pigs on terrestrial plant and animal communities is with a fresh damage index similar to the one developed by Engeman et al (2001). This index is measured from identifying the number of sites of fresh rooting per km of the route between PTI plots in order to develop a simplistic description of pig damage to terrestrial plant and animal communities. The incidence of fresh rooting along the fixed route between PTI plots forms a secondary indicator of pig activity.

ii. Other damage indices

Other methods to quantify feral pig effects on ecosystems are included in the feral pig chapter of the ranch-wide management plan and may be applicable for the summer. One method involves geo-referencing such pig signs as rooting and wallowing with a GPS unit and then merging GIS files of

vegetation with the GPS locations in order to associate the area of impact and intensity of damage within each vegetation type and gain an estimate of the total damage (Chavarria et al. 2007).

Another method involves using random stratified sampling of vegetation to measure the extent and intensity of rooting and wallowing by feral pigs (Chavarria et al. 2007). In any one of their several study areas, 20-40 randomly located strip transects, comprised of fixed segments 10 m wide by approximately 1 km long, were surveyed. A random stratified sample of survey segments were selected for each major vegetation type. Distance to water, park roads, oil and gas pipelines, and park recreational trails were also recorded. Half the transects were placed <50 m from major hydrological sources (i.e., creeks and rivers), while others were placed >500 m from these water sources. Likewise, half the transects were placed <50 m to a park road, while others were placed >500 m from a park road. We plan to establish a transect system in conjunction with the PTI system that will incorporate elements of all of these methods. The vegetation classifications will be evaluated by the Bren team once they have established the PTI plots. Damage plots will be placed off of the PTI transects at a set distance. Riparian damages will be recorded by a separate transect system. These transects will run perpendicular to waterways with plots placed at regular intervals. The lengths of these plots are proposed to be 100 m with plots every 10 m, but the feasibility of this will be assessed once the Bren team is on the ranch.

3. Analysis of feral pig management options of greatest value to the Conservancy

The project will make recommendations to the Conservancy for potential management strategies based on the ability of each strategy to provide the greatest value in terms of efficacy, ecological and economic benefits, stakeholders' buy-in, and legal feasibilities. Potential management strategies include maintaining the status quo, increasing hunting pressure, increasing natural predation, trapping and culling, fencing pigs in certain areas or out of certain ecologically and economically important areas, eradication, or some combination of the aforementioned techniques. We will accomplish this using a multivariate analysis that incorporates benefit-cost analysis and non-monetary risk analysis, including stakeholder acceptability analysis and legal barriers analysis.

A. Benefit-cost analysis

As Dr. Kunkel notes in his literature review, "estimating the amount and the associated value of hog damage allows for the application of benefit-cost analyses in order to evaluate the need and success of hog control from an economic perspective, or to compare the economics of hog management approaches (Engeman et al 2007a)" (Kunkel Feral Pig Management Chapter 2013). The project will use the benefit-cost model approach to determine which management strategies are most applicable and useful for Tejon. This analysis will begin to be developed over the summer by the other three students not interning at Tejon and will be further developed during the fall quarter.

B. Non-monetary risk and benefit analysis

i. Stakeholders Acceptability Analysis

We will conduct a stakeholder analysis to assess acceptability of each management option by the various stakeholder groups. According to the Stakeholder Analysis Standard developed by World Wildlife Fund, there are three steps that need to be implemented in the analysis: 1) identifying the key stakeholders and their interests (positive or negative) in the project; 2) assessing the influence of, importance of, and level of impact upon each stakeholder; and 3) identifying how best to engage stakeholders (WWF 2005).

Below is a figure of potential stakeholders who will have influence in, and who will be impacted by our recommended management strategies, modeled after the WWF Stakeholder Analysis Matrix.

Figure 1. Stakeholder Analysis Matrix

Stakeholder	**Stake/Mandate**	**Potential Role in Project**	**Marginalized?**	**Key?**
Tejon Ranch Conservancy	Cultural values			
TRC Hunting Program	Profit			
TRC Land Lessees	Profit			
Hunters	Cultural values, lifestyles			
Future Developers of TRC land	Profit			

Tejon Mountain Village future landowners	Lifestyle			
Tejon Ranch Neighbors	Cultural values, profit			
Environmental Organizations	Cultural values			
Animal Rights Groups	Cultural values			

ii. Legal Feasibility Analysis

As noted earlier, California classifies feral pigs as a big game species and manages the populations throughout the state. Hunters wishing to take a pig must purchase the required tag, and private landowners wishing to eliminate pigs that are causing damage to their property must secure a depredation permit before beginning to remove the species. In order to obtain a pig depredation permit, landowners must apply for the permit and show that their property is being or threatened with damage or destruction. The permit will specify how the pigs may be taken and how carcasses will be disposed of. If a permit is issued, permit holders must report their take to CDFW on a monthly basis. At Tejon Ranch, the Conservancy may be able to obtain a depredation permit if they can show that the ranch property is being damaged or destroyed by wild pigs. As stewards of the property, the Conservancy may be able to obtain depredation permits to cull the pig population on the ranch. In the event that CDFW chooses to delist pigs as a game species, feral pigs would be considered a pest species and anyone would be allowed to take them without a permit. This would allow the Conservancy to remove as many pigs as possible, while TRC could continue to charge for access to the ranch in order to hunt pigs. There is no indication that CDFW is considering this option at this time.

While these general guidelines are well established, there is a great deal of uncertainty about what options Tejon Ranch has for managing pigs within that broad context. We will engage in a thorough analysis of this legal regime and how it will dictate any management strategies for Tejon Ranch. We will also utilize this information to help Tejon Ranch understand pig management in a larger, statewide context. This analysis will primarily take place through contacts with the California Department of Fish and Wildlife and other private ranches that have implemented feral pig management programs. We will incorporate this analysis into a larger recommendation about feral pig management in California.

4. Data Catalog

A. Geospatial data

i. Feral Pig Abundances and Spatial Distribution – Indices of feral pig abundances and spatial distribution will be obtained by summer interns.
ii. Ecological Effects – Indices of ecological effects of feral pigs will be developed using GIS vegetation layers already developed by previous group projects.

B. Survey data

i. Hunting Pressure - Data on hunting takes will be obtained from the Tejon Ranch Hunting Program to assess effects of hunting pressure on pig population dynamics.
ii. Pig Abundances and Spatial Distribution - Field observations will obtained from interns, hunting guides, lessees, and hunters to estimate the extent, structure, and effects of the current population.
iii. Stakeholder Values – Survey and interview data on stakeholder attitudes, preferences, values, and demographics will be collected using an approved survey.

5. Deliverables

A. The Tejon Ranch Conservancy deliverables

i. Indices of feral pig abundances, spatial distribution, and ecosystem effects in certain areas at Tejon
ii. Multi-Criteria Analysis: We will analyze and score the following criteria to determine the most suitable management strategy for feral pigs on Tejon Ranch:
    Cost-Benefit Analysis
    Stakeholder Analysis
    Legal Analysis
iii. Recommendations to the Tejon Ranch Conservancy about which strategies will provide the greatest value to the Conservancy in terms of efficacy, cost, practicality, stakeholder buy-in, and ecological and economic benefits

B. Academic deliverables

i. Work plan
ii. Academic defense presentation
iii. Final report
iv. Project brief
v. Project poster
vi. Final Presentation

6. Milestones

Spring Quarter 2013	
By Mon April 29	Advisory committee selected and confirmed
Mon May 27	Send revised work plan to faculty advisor, client, and external advisors
By Mon May 27	Submit survey draft soft copy for review to Michael Henderson and Michael White
By Jun 7	Host work plan review meeting with faculty advisor, client and external advisors by this date
Fri Jun 7	Send web link for GP website to GP coordinator
Fri Jun 14	Submit final work plan to faculty advisor, client and external advisors
Fall Quarter 2013	
Mon Sept 23	Internship data on indices of population abundances, spatial distribution, and ecological impacts compiled with preliminary report of findings
Mon Sept 23	Survey results collected and coded
By Fri Nov 15	Host fall review meeting with faculty advisor, client, and external advisors
Fri Dec 13	Written progress report due to faculty advisor
Winter Quarter 2014	
Fri Feb 21	Draft of final report due to faculty advisor
Fri Feb 21 & 28	Group project defenses
Fri Mar 7	Submit final presentation program abstract to GP coordinator (Template sent out by GP coordinator 2 weeks prior)

Fri Mar 7	Draft project brief due to faculty advisor
Fri Mar 7	Draft project poster due to faculty advisor
Fri Mar 21	Final report (.pdf version) due to faculty advisor and GP coordinator
Spring Quarter 2014	
Fri Apr 4	Final project brief and project poster (.pdf version) due to faculty advisor, GP coordinator and posted on GP website
Fri Apr 11	Master's project final presentations (hard copy poster will be collected by GP Coordinator after final presentations)

7. Group Management Plan

A. Group Structure

Project Manager: Elizabeth Hiroyasu
Data Manager: Adam Kreger
Financial Manager: Max Ludington
Web Manager: Emily DeMarco
Internship Manager: Jocelyn Christie

Faculty Advisor: Naomi Tague
External Advisors:
Dr. Frank Davis will assist in the design of the project and research over the summer. His familiarity with Tejon Ranch and the surrounding area will help us to assess the feral pig situation specifically at Tejon Ranch.

Dr. Bruce Kendall will assist in population analysis and model design to determine indices of feral pig abundance and spatial distribution on the Ranch.

Dr. Kyran Kunkel will assist both with field survey design and development of a feral pig population model. His familiarity with the ranch and prior research and wildlife assessment of the ranch will help us to identify effective strategies for feral pig management on the ranch.

B. Meeting Structure

During spring quarter 2013 weekly meetings will occur in the Visitor's Center on Mondays at 9AM with Dr. Tague. For the two weeks Dr. Tague is unable to be present, the group will use this time to engage with other external advisors. We will also submit written deliverables to Dr. Tague and schedule additional meetings as necessary. Emily DeMarco will be in charge of scheduling all meeting rooms and equipment (such as telephones, conference lines, etc) and indicating the meetings on Corporate Time. Elizabeth Hiroyasu will draft meeting agendas and distribute them in a timely fashion. Meeting notes will be taken by all group members and compiled on a common, shared drive.

C. Guidelines for interacting with faculty advisors, clients, and external advisors

Elizabeth Hiroyasu will be the primary contact with faculty advisor, client, and external advisors. Additional professionals consulted by the group will be assigned to different group members as points of contact.

D. Systems to ensure critical tasks are completed on time

The group will specify important due dates and tasks on a common Google Calendar. During weekly meetings, tasks will be delegated among the group with assigned due dates and weekly goals. It is the responsibility of all group members to ensure that deadlines are met. The project manager will help remind the group of upcoming deadlines and tasks.

E. Procedures for documenting, cataloging, and archiving information

Documents, contact information, messages, calendar, website, budget projections, and expenditures will be tracked using Google Drive and will be accessible to all group members. The Google Calendar will be managed by the project manager. Scientific literature used in the literature review for background will be managed using Zotero software.

F. Overall expectations of group members and faculty advisor

Group members are expected to be involved in all aspects of project and be responsible for collaborating on all deliverables. The faculty advisor is expected to contribute feedback in a timely manner and help to ensure that the group is on target.

G. Conflict resolution process

To avoid conflict, communication is expected to be clear and open between group members and all outside contacts. Should any problems arise, they will be dealt with promptly. Tasks may be re-negotiated. and problems will be discussed. If the group is unable to come to agreement, we will seek the help of our faculty advisor or Bren School administration.

8. Budget

Item Description	Cost
Internships	**$12,000**
Equipment: cameras, digital storage, software	**$2,000**
Presentation Expenses	**$50**
Poster Production	**$50**
Travel costs to and from Tejon Ranch	**$300**
Parking Passes	**$50**
Printing and copying	**$250**
Food Items	**$200**
Phone Calls	**$50**
Miscellaneous	**$1550**

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Appendices

A. Land Owner/Lessee Survey

See attached PDF.

B. Hunter and Hunting Guide Survey

See attached PDF

C. Policy-Maker Interview Guide:

Overall goals for this series of interviews

While the questions below are designed to elicit key answers, conversations will naturally veer away from the guide from time to time. Please consider the goals when conducting the interview and choose appropriate questions based on what you think will generate the most useful responses for achieving these goals:

- Understand the context and legal framework under which feral pig management operates in California, specifically on private lands.
- Understand the processes that Tejon must complete in order to change its management strategies.
- Pick up on any key changes in pig management in the state. Any changes specific to Tejon's region?
- Pick up on any key trends in pig populations in the state. Any key trends specific to Tejon's region?
- Be able to describe the management options (from a policy point of view) available to Tejon plus the steps that must be taken to implement each strategy. Understand the costs and feasibility of each of these strategies.
- Develop a key contacts list for Tejon if they wish to pursue a specific strategy.

The Questions:

"Thank you for taking time out of your day to speak with us. As part of our project through the University of California at Santa Barbara, we are trying to get a better understanding of feral pig management in California. When appropriate, give a more detailed description of Tejon project and setting. We have come up with some questions to help us understand some of the relevant issues surround pig management in California. Please feel free to interject at any time or correct us if our questions seem to be based on bad information. "

1) What function does your office serve with regards to feral pig management in California?

2) Does your agency work with private landowners or just public landowners?

3) What are the guidelines under which your agency deals with feral pigs? Are there written documents available that explain this?

4) What are the steps that landowners must take to be in compliance with your agency's oversight (purchasing pig tags? applying for depredation tags? etc?)? How often do landowners interact with your office? In what ways?

5) How do private landowners seeking to evaluate or change their tactics interact with your office? Is there a set process for this? How often does this occur? Do you send employees into the field to evaluate private lands? What steps must a private landowner take in order to make a significant change in their management practices?

6) What is your overall impression of pig management in California? Do you feel differently about management on public lands than private lands?

7) What do you think the overall costs and benefits of California's feral pig populations are? (This does not need to be quantified. Encourage respondent to consider this issue broadly)

8) How has pig management changed in California during your tenure? From a policy perspective? From a scientific perspective? From a management perspective? From a population perspective? Do you think that these changes have been good or bad?

9) Do you have any recommendations that you believe ought to be implemented to feral pig management in California?

10) Do you have any advice for private landowners attempting to control feral pig populations? Are you aware of any resources available to landowners? Do you have any contacts with whom you believe we should speak?

11) Any final thoughts or comments?

"Thank you for taking time out of your day to speak with us. We are extremely grateful and would love to follow up with you if we have any further questions. Thanks again."

D. Map of Tejon Ranch Highlighting Tejon Canyon and Transects

See attached PDF.

E. Proposed Coordinates For Start of Transects

Group A
1. 118°41'53.715"W 35°2'26.636"N
2. 118°39'32.438"W 35°2'32.366"N
3. 118°39'32.438"W 35°2'32.366"N
4. 118°32'29.415"W 34°59'25.183"N
5. 118°33'23.147"W 34°59'20.96"N

Group B
6. 118°36'57.899"W 34°59'12.979"N
7. 118°38'3.579"W 35°0'3.561"N
8. 118°39'13.757"W 35°1'22.758"N
9. 118°41'15.385"W 35°1'1.3"N
10. 118°41'15.664"W 35°1'43.755"N