California Department of Parks and Recreation
Natural Resources Division

Monitoring Feral Pig *(Sus scrofa)* Activity at Wilder Ranch State Park

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by
Craig Swolgaard
Environmental Services Intern
Natural Heritage Section
Inventory, Monitoring, and Assessment Program
1416 9th Street, room 923
Sacramento, CA 95814
(916) 653-6656
email: cswol@parks.ca.gov

I.) Introduction

The effects of exotic species on the natural communities of parklands can be devastating. In the case of large mammals, such as feral pigs (*Sus scrofa*), behaviors can cause physical damage to certain environmental features, introduce exotic plant species, and degrade the quality of the ecosystem. Feral pigs have been in California since they were introduced by agriculture in the late 1700s. Since that time pigs escaped or were set free, and established feral populations in many areas. Recently, pigs have been purposefully introduced on private lands for sport hunting purposes. In some instances, these pigs have roamed off these private lands and onto public lands, including state parks. Overall, California has experienced an increase both in population and range expansion of feral pigs (Waithman, et al. 1999). In Santa Cruz County, it is estimated that one third of the land area provides permanent habitat for feral pigs (Hoehne 1994).

One feature of pig biology is their high reproductive rate. A sow reaches reproductive age in 6-8 months, and can have as many as 5-8 young in a litter, with two litters in a year (Breuer 1987). Populations can grow very quickly. From late winter through mid-summer, pigs prefer rooting in open, grassy areas for corms and bulbs. During the fall and winter, they switch to the oak woodlands in search of acorns. Pigs also are known for their wallowing in wet and muddy basins or streambeds. Damage to riparian or wetland areas have been caused by such behavior, including erosion problems and a possible increase in fecal coliform levels in streams. Whether or not feral pig rooting causes an increase in exotic plant species is unknown (Kotanen 1994, 1995).

Wilder Ranch State Park has had a large population of feral pigs for some time (Ag Comm. 1990). The rooting damage to the soil can be seen in most grassland areas, as well as within the oak forests. A control program of trapping and removal was started in the late 1990s to control the number of pigs in the park (Appendix 2, figure 8). This study plan addresses the monitoring of pig presence, in order to assess the effectiveness of these efforts, and the extent of pig activity in the park.

The objectives of this study are to:

1.) Locate the general areas of pig activity in the park.
2.) Monitor for presence/ absence of pig activity in the park over time, using a past study for comparison.
3.) Assess extent and types of damage to vegetation and soils from pigs.
4.) Record plant species associated with pig activity in the park.
5.) Establish a workable protocol by which the prior objectives can be accomplished and present management efforts can be evaluated.

The location of the study was Wilder Ranch State Park, and included all major grassland areas as well as some woodland areas. All data was recorded from transect plots during the months of June- August of 2001 by one person.

Other feral pig studies have been done in Australia, Hawaii, and California (Hone 1988, Hone & Stone 1989, Katahira, Finnegan & Stone 1993, Kotanen 1995, Sweitzer et al. 2000). In California, research locations include Annadel State Park (Barrett, Fitzhugh, & Goatcher 1987), Henry Coe State Park (Sweitzer et al. 2000), and other locations in the Coast Range. A study in Santa Cruz County was completed in 1990 by California Department of Parks and Recreation. It included Wilder Ranch State Park and compared pig damage before and after a drought. It was based on these studies and input from Dr. Reg Barrett, a UC Berkeley professor, that the methodology was developed. See Appendix 1 for contact information.

II.) Methods

A.) Development of Methodology

Before developing the methods that were used, research was done on recent studies of the feral pig, including its biology and behavior. Several studies in the literature reflect the concern over which methods best measure pig presence or abundance (Hone 1988, Hone & Stone 1989, Hone 1995). This is a problem still being worked on. Knowledge of an organism's biology should be one of the cornerstones of any kind of monitoring study. It was noted that two main forms of *Sus scrofa* occur in the Wilder Ranch State Park: feral domestic pigs and European wild boars, including various hybrids of the two. There is some difference in appearance and habits between the two forms, but both are destructive to habitat.

Subsequently, a large part of Wilder Ranch State Park was scouted for areas of pig rooting and these areas were described in terms of damage extent. It was decided to list the most abundant plant species within the rooting area as a way of characterizing the habitat both frequented and disturbed by feral pigs. Scouting these known areas of pig activity helped the field technician become familiar with the physical signs of pig activity, including rooting, scat, wallowing areas, cover, and footprints. District ecologists were conferred as to the major areas of pig activity they had found in Wilder Ranch State Park during their pig management program, and the behavior of the pigs in general.

An attempt was made to make the monitoring method accurate and helpful, yet practicable and not overly time-consuming. The basis for the transect method used came from consultation with Dr. Reg Barrett, one of California's foremost authorities on feral pigs (Barrett pers.com. 2001). It consists of a simple 1-km transect line with plots set up every 100 m. He and his colleagues have been using this simple method with good success (Barrett, Fitzhugh, & Goatcher 1987). One admitted drawback is the difficulty of using this method in areas of dense vegetation. A second, random plot method was used in this study for small grasslands and woodlands. It was a hybrid of the transect method, developed with solving the dense vegetation problem in mind. Since neither small grasslands nor woodlands were conducive to using a straight 1-km transect, it was thought that an existing trail or road could stand in for a transect line, and fewer plots per transect used. Plots would be placed on either side of the transect line in a random manner. The idea was proposed to Dr. Barrett for his opinion (Barrett pers.com. 2001). His only concern was the possible bias introduced by placing plots close to trails, causing an overestimation of pig presence, because pigs tend to travel along trails. This was partly remedied by placing all plots a minimum of 10 meters from the trail or road, at random distances. Also, results need not be extrapolated to areas of the park without trails.

After the random plot method was designed, concern over whether it was practicable prompted a trial run. No pig presence data was collected, other than observations. Selected trails were walked as transects, and at each 100 meter juncture along the transect, distance that access was possible was estimated for both sides of the trail. Both sides were also rated for overall accessibility of 100 meters, and degree of poison oak density. Accessibility was rated at a scale of 1-4, 1 being "easy" and 4 "impossible." Poison oak was rated on the same scale, with 1 being "absent" and 4 being "high density." Five "trail-transects" were tried, yielding a total of 39 access points. The results of this preliminary study are found in the "Findings" section of this report.

B.) <u>Study Sites</u>

The first step was to locate known areas of pig activity. Pig sign and disturbed vegetation has been found all over the park, in open grassland as well as in dense woodlands. In order to select the best sites for transects, a survey was conducted to scout for general areas of visible pig damage and to assess the quality of roads and trails in the park. The most obvious signs of pig activity were in the grassland areas, but pigs had also been seen in wooded areas. Since a comparison would be made between grassland and woodland plots, it was decided to stratify the study sites by habitat type. USGS topo maps of Wilder Ranch State Park (Santa Cruz & Felton quadrangles) were combined and divided into basic habitat regions, using aerial maps and the vegetation maps created by IMAP in Arcview. Grassland and woodland areas were delineated on the map by polygons. Since two methods were to be used to monitor pig activity, sample sites were divided into two groups: large grasslands (transect method) and woodlands/small grasslands (random plot method). The methods themselves will be covered in the next section.

On the topo map, the large grassland areas of Wilder Ranch State Park were divided into 10 polygons, each designated with a code (PG 1, PG 2, etc.). From viewing the topo map, it appeared possible to fit one or more 1-km transects within each of these areas. An attempt was made to sample all ten polygons during the study, but for three of them (PG4, PG5 & PG8) it was not possible to complete a whole 1-km transect due to topographic constraints. PG 8 was surveyed by the random plot method and was designated TOT. The eight study transects completed were in grassland polygons PG 1, PG 2, PG 3, PG 6, PG 7, PG 9 (2), & PG 10 (see map, Appendix 2).

For woodlands and small grasslands, sample sites were identified by the trails or roads that are used to access them (i.e., a transect using Twin Oaks Trail will be labeled TOT). The following trails or roads were used as transects for woodlands and small grassland plots (refer to map):

Eucalyptus LoopTrail (EULT)
Brian Campbell Road (BCR)
Chinquapin North Spur (CNS)
Engelsman Loop Trail (ELT)
West Access Road (WAR)
Enchanted Loop Trail (ENLT)
Enchanted Loop Trail Woodland (ENLTW)
Twin Oaks Trail (TOT)
Lime Kiln Trail (LKT)

Total number of plots for large and small grasslands was ninety-two, and for woodlands nineteen, making a total of one hundred eleven plots. Locations of the study sites were chosen to get a representative view of the whole park. See the map of Wilder Ranch State Park, showing all study sites, in Appendix 2.

C.) Equipment Used

The field technician took the following equipment in a back pack to the study sites each time a transect was done:

- Trimble Geoexplorer 3 GPS unit
- Canon digital camera with extra memory chip
- Map of the park with the study sites marked
- Compass
- Field magnifying lens
- Botanical field guide or key
- Four staked flags
- Clipboard with data sheets, pencils
- Sunscreen, Hat
- Insect repellant (ticks are abundant)
- Tecnu (for poison oak exposure)

In the office, Trimble's GPS Pathfinder Office 2.80 and Arcview 3.2 were used to transfer GPS waypoints onto a GIS-generated map format.

D.) Methodology Used

Two methods were used to monitor feral pig activity, one for large grassland areas and another for woodlands/small grassland areas. Small grasslands were considered to be those in which a 1-km transect could not fit. There are two purposes for these methods. One purpose is to express pig presence as the proportion of total plots that have some sign of pig activity. The other is to identify the plants species associated with pig activity in the park. It took a total of 7 full workdays to complete all of the grassland transects, for one person. The woodland transects took an extra 4 days. Graphic examples of transects are found in Appendix 2, and copies of the field data sheets are found in Appendix 3.

<u>Large Grasslands</u> (Transect Method)
10 m by 10 m plots were arranged every 100 m along a 1-km transect. Plots were monitored to detect presence or absence of pig activity, to describe type and extent of pig sign, and to identify plant species composition. The protocol was as follows:

1.) Using a map, a point was chosen along a road or trail that allowed for a 1-km transect to be readily accessed. The map was referred to be sure a transect of that length fit.
2.) After driving to that point, a randomly chosen starting point was reached away from the road or trail.
3.) Referring to the topo map, a compass bearing was taken that would allow for a 1-km transect in grassland and it was recorded on the data sheet (see Appendix 2). This bearing is the direction followed.
4.) For reference purposes, four photographs were taken from the starting point, in clockwise order, at 90° angles from each other, in alignment with the transect. These photographs will be used in conjunction with UTM coordinates, to relocate the transect if necessary.
5.) A GPS reading was taken at the starting point and the UTM coordinates recorded for later reference or downloading onto GIS system. *Note*: no plot was surveyed at the starting point.
6.) Following the designated compass bearing 100 m was measured out by calibrated footsteps. The UTM coordinates and pertinent location information was recorded as described in step 5.
7.) A 10 m by 10 m plot was positioned in relation to the transect line by random choice (there are four possibilities, see Appendix 2, figures 1 & 2). The transect line formed one of the edges of the plot. The position was recorded on the data sheet.
8.) The 10 m by 10 m plot was measured out, flags placed at each corner.
9.) The entire plot was visually inspected for any sign of pig activity. Presence or absence of pig sign, type of pig sign, and all other pertinent information was recorded on the data sheet. Types of pig sign include rooting, feces, tracks, wallowing and cover. Bushes or wet spots were checked in the plot for tracks, feces, or hair that would indicate use. If the plot included brush or wet areas that could potentially be used by pigs, but were not, a note of this was made.
10.) The most abundant three species of grasses, forbs, shrubs, and trees were estimated visually and recorded. Later in the season, the California Native Plant Society (CNPS) Vegetation Rapid Assessment protocol (Appendix 3) was used to record the dominant species of grasses, forbs, shrubs or trees in the plot.

11.) The designated compass bearing was followed to the next 100 m point and steps 4–10 were repeated. At the last sample point, four photographs were taken in the same manner as described in step 4. A total of ten plots were done for a 1-km transect.

12.) If a number of transects were being done in one grassland polygon, they were separated by at least 100 m at any given point.

<u>Woodlands/ Small Grasslands</u> (Random Plot Method)

In this method, a trail or road was used as the "transect line." This method was tried due to the problems inherent in attempting a 1-km transect through steep, thickly wooded terrain. Every 100 m, 10 m by 10 m plots was placed randomly at a distance of 10 – 100 m perpendicular from the trail or road. Plots were monitored to detect presence or absence of pig activity, to describe type and extent of pig sign, and to identify dominant plant species composition. The protocol was as follows:

1.) The transect began at a point along the road or trail within one of the two habitat types described (woodland or small grassland). The starting point was a random number of steps (i.e. 10 – 100) into that habitat. The transect was designated on the data sheet as the letter code of the trail or road used as a transect (see the section: Study Sites). This code was followed by a number, zero for the starting point. This code was entered as a new data file in the GPS unit, and the UTM coordinates were recorded. For example, the third plot on Twin Oaks Trail was recorded as TOT-3P.
2.) 100 m was measured off along the trail, using calibrated footsteps. UTM coordinates were recorded for this point under "trail waypoint" on the data sheet.
3.) A side of the trail was randomly chosen (i.e. a coin toss) and a randomly chosen number of meters (10–100) were stepped off into the small grassland or woodland, in a direction perpendicular to the trail. If a perpendicular direction is not possible, choose a direction that is and record it as a compass bearing. Side of trail and distance to plot were recorded. It was assured that the plot would cover either grassland or woodland habitat (not both). The UTM coordinates were recorded under "plot waypoint" on the data sheet. This point represented one of the four corners of a 10 m by 10 m plot, each side facing one of the four cardinal directions. Which of those corners was determined by random choice. Four photographs from each of the four cardinal directions (North, East, South, and West) were then taken.
4.) A 10 m by 10 m plot was measured off, placing flags at each corner.
5.) The entire plot was scanned for any sign of pig presence. Presence or absence of pig sign, type of pig sign and all other pertinent information was recorded on the data sheet. Types of pig sign include rooting, feces, tracks, wallowing and cover. Bushes or wet spots in the plot were checked for tracks, feces, or hair that would indicate use. If the plot included brush

or wet areas that could potentially be used by pigs, but were not, this was noted.

6.) The most abundant three species of grasses, forbs, shrubs, and trees were estimated and recorded. Later in the season, the CNPS Rapid Assessment protocol was used (Appendix 3) to record the dominant species of grasses, forbs, shrubs or trees in the plot.

7.) After returning to the trail, steps 2 –6 were repeated, until seven plots were surveyed. Because of problems with impassable terrain, few of the transects done by this method included any more than seven plots.

E.) Parameters Measured

- Sign of pig presence

  Signs of pig presence were divided into five categories:

  1.) Rooting- This is the most visible sign of pig activity, and considered to be the most accurate indicator of pig presence (Hone 1988). In grasslands, rooting appears as areas of open ground, where the root layer has been plowed aside by the tusks of the pig (Appendix 2, figure 7). These areas of exposed soil can be smaller than a doormat or cover hundreds of square meters. In the woodlands, rooting is more difficult to detect, especially under tree canopies, where piles of leaves appear to be brushed aside.
  2.) Scat- Pig scat has been used in the past as an indicator of pig presence (Hone 1988), and though it is not as accurate as rooting, it was considered an important parameter. It is variable in its size, shape and texture (Appendix 2, figures 5 & 6), depending on the diet of the pig.
  3.) Tracks- The tracks and track patterns of feral pigs vary between wild boars and domestic strains (Appendix 2, figures 4 & 6). Finding tracks is not only an indicator of pig presence, but also helps in locating trails used by pigs.
  4.) Wallows- Pigs are attracted to wet marshy areas or pools that are used as wallows. Wallows are recognized by disturbed muddy areas with trampled plants, tracks, or scat close by. Since wallows are frequented by pigs throughout the season, this is a good general indicator of their presence.
  5.) Cover- Certain types of brush are utilized as cover by pigs, depending on their safety and proximity to resources. This cover is used for hiding, resting, or sleeping. When scanning plots that include brushy areas, these areas should be checked for bedding scrapes, tracks, scat, or hair stuck to the lower branches.

- Extent of rooting damage

  The amount of rooting damage was quantified by visual estimation and expressed as percent damage of total plot area (% plot covered). The best way to do this is to mentally divide the plot into quarters and add together all percentages.

- Age of damage
  It helps to know whether the damage is recent or from earlier in the season, especially in the context of an active management program (Katahira, Finnegan & Stone 1993). The method used to estimate this was by scanning the damaged area for any emerging new plants. A recently damaged area should not have any new plants coming up. Age was recorded as "recent" or "last season."

- Plant composition
  Although surveying the plot for plant species may not be useful in judging the success of a management program for feral pigs, the information is helpful in other ways. For permanent plots it will help in monitoring the introduction of new plant species to damaged areas, especially exotics (Kotanen 1994, 1995). It might detect rare or endangered plants in the park. Also, the information may aid in modeling efforts, such as a habitat suitability index for pigs. Refer to the CNPS Rapid Assessment protocol in Appendix 3. The negligible amount of extra time it takes is worth the effort.

III.) <u>Findings</u>

A.) <u>Study Site and Transect Locations</u>

The general locations of study sites, along with the beginning and ending points of each transect are given. A map showing the exact locations is found in Appendix 2, and on the attached CD as a shapefile.

- <u>PG 1</u> (10 plots)- This large grassland is located on the far-west side of the park, its west edge bordering the Majors Creek ravine. The access road (West Access Road) is found by driving about 6 km north on Hwy 1, from the park entrance, and turn right at a paved gated road. PG 1-0 is about 1 km up the road, just past where it forks (on the right fork). The transect and plot locations are as follows:
  PG 1-0 / UTM Waypoint: N 4093573 / E 577597 (Compass bearing: 30°)
  PG 1-10 / UTM Waypoint: N 4093573 / E 577597
- <u>PG 2</u> (10 plots)- This large grassland is due east of PG 1, its east border along Baldwin Creek ravine. To get there, follow Hwy 1 north about 4.5 km from the park entrance, to Four Mile Produce on the right. Park off the highway and walk north, past the agricultural fields and up the steep hill to PG 2.
  PG 2-0 / UTM Waypoint: N 4092587 / E 577770 (Compass bearing: 20°)
  PG 2-10 / UTM Waypoint: N 4093443 / E 578025
- <u>PG 3</u> (10 plots)- A large grassland that borders Baldwin Creek ravine along its west edge. It is accessed by driving to Baldwin Loop Trail, about 4 km north of the park entrance on Hwy 1. Before crossing Baldwin Creek, pull off to the right and park where a gated driveway goes down toward a private residence. Walk through the gate and downhill, turning right onto a trail that hugs the fence line of the residence. Take the trail (Baldwin Loop Trail) north toward

the ravine where the creek is. Pass an old barn and a fenced corral on the left. Remain on the trail until it passes through the ravine and climbs out of it. The grassland to the left and uphill is PG 3.
PG 3-0 / UTM Waypoint: N 4092643 / E 578357 (Compass bearings: 30° up to PG 3-4, then 20° up to PG 3-6, then 10° to PG 3-10)
PG 3-10 / UTM Waypoint: N 4093484 / E 578701

- PG 6 (10 plots)- A large grassland bordered by Sandy Flat Gulch Creek on the west and Peasley Gulch Creek on the east. From the Wilder Ranch SP entrance, drive into the park, past the fee kiosk and straight downhill to the Cultural Center. Turn left and pass through the buildings, keeping left. Pass under the freeway and veer left at the fork, until the road switches back to the left. Follow the road up the hill to PG 6. The transect is located in the broad, flat prairie to the left of the road, before it climbs into the woods along Peasley Gulch. During part of the season, a pig trap was stationed here.
  PG 6-0 / UTM Waypoint: N 4092505 / E 581349 (Compass bearings: 265°)
  PG 6-10 / UTM Waypoint: N 4092357 / E 580402
- PG 7 (10 plots)- This large grassland is located on the southeastern edge of the park, its east border along Wilder Creek ravine. To get there from the Wilder Ranch SP entrance, drive into the park, past the fee kiosk and straight downhill to the Cultural Center. Turn left and pass through the buildings, keeping left. Pass under the freeway and veer left at the fork, following straight. After crossing Peasley Gulch Creek, the road forks. The transect is located along the right fork about 1.5 km uphill, but either fork will arrive at PG 7.
  PG 7-0 / UTM Waypoint: N 4092363 / E 582143 (Compass bearing: 10°)
  PG 7-10 / UTM Waypoint: N 4093233 / E 582260
- PG 9 (20 plots)- This large grassland has a west and east section, separated by a wooded ravine. North of the ravine is a grove of eucalyptus trees. The eastern edge of PG 9 borders Peasley Gulch. This study site contains two transects (a & b), with ten plots in each. To get there, enter the park through the Twin Gates entrance (off Empire Grade Road) and follow the dirt road to the first fork. Take the right fork (Chinquapin Trail) and stay on this road until reaching the eucalyptus grove. This whole grassland to the north and south is PG 9. Transect (a) starts northeast of the eucalyptus grove and follows the eastern half of PG 9. Transect (b) also begins north of the eucalyptus grove, but follows through the western half of PG 9.
  PG 9a-0 / UTM Waypoint: N 4095811 / E 580911 (Compass bearing: 170°)
  PG 9a-10 / UTM Waypoint: N 4094716 / E 581870 (estimated from Arcview)
  PG 9b-0 / UTM Waypoint: N 4095741 / E 580839 (Compass bearing: 190°)
  PG 9b-10 / UTM Waypoint: N 4094804 / E 580725
- PG 10 (10 plots)- A large grassland located east of PG 9, with its western edge bordering Peasley Gulch. To get there, enter the park through the Twin Gates entrance (off Empire Grade Road) and follow the dirt road to the first fork. Take the left fork (Long Meadow Trail) and stay on this road until reaching PG 10, a long grassland area. The transect begins at the north end, where the road emerges from the woodland.

PG 10-0 / UTM Waypoint: N 4095625 / E 581440 (Compass bearing: 155°)
PG 10-10 / UTM Waypoint: N 4094714 / E 581865

- WAR (1 plot)- This transect is located at the end of the west access road, at the west end of the park. West Access Road is found by driving about 6 km north on Hwy 1, from the park entrance, and turn right at a paved gated road. Follow about 1 km up the road, taking the right fork and continuing until it ends at a fence line. Only one woodland plot was done, 125 meters from the fence line.
  WAR start / UTM Waypoint: N 4095080 / E 578500 (estimated from Arcview)
- BCR (4 plots)- The transect on "Brian Campbell Road" was done off of park property, close to the sand hills in the upper section. To get there, drive up Empire Grade Road to Smith Grade Road, and turn left. About 1.25 km down Smith Grade Road, turn left at a green state park gate (key needed). Follow the dirt road about 1 km to the start of the transect.
  BCR start / UTM Waypoint: N 4096130 / E 580212
  BCR end / UTM Waypoint: N 4096410 / E 580030
- CNS (3 plots)- Chinquapin North Spur is a short transect with only three woodland plots. It is reached by entering the park through the Twin Gates entrance (off Empire Grade Road). Follow this road to the waypoint, on the right, where a trail enters the woods.
  CNS start / UTM Waypoint: N 4096921 / E 581350
  CNS end / UTM Waypoint: N 4097116 / E 581024
- ENLTW (3 plots)- The lower end of the Enchanted Loop Trail was followed as a transect, but only passed through woodland. The trail begins at PG 3, at the top of Baldwin Creek ravine, and descends into the wooded ravine, dominated by Tanoak (*Lithocarpus densiflora*). From the Wilder Ranch SP entrance, drive into the park, past the fee kiosk and straight downhill to the Cultural Center. Turn left and pass through the buildings, keeping left. Pass under the freeway and veer left at the fork, until the road switches back to the left. Follow the road up the hill for about 4 km, until it reaches a junction with a paved road. Turn left and then make a right on a dirt road that leads to the Baldwin Loop Trail. Follow this road for about a kilometer and veer to the right, where the Enchanted Loop Trail starts at the edge of the ravine.
  ENLTW start / UTM Waypoint: N 4093910 / E 579135
  ENLTW end / UTM Waypoint: N 4094100 / E 579332
- ENLT (7 plots)- This is a transect that follows the upper end of Enchanted Loop Trail and includes five small grassland plots and two woodland plots. To get there, enter the park through the Twin Gates entrance (off Empire Grade Road) and follow the dirt road to the first fork. Take the right fork (Chinquapin Trail) and stay on this road until reaching the eucalyptus grove. Turn right and follow for about 1 km until reaching the intersection of the Enchanted Loop Trail. Park and follow the Enchanted Loop trail northward.
  ENLT start / UTM Waypoint: N 4094107 / E 580055
  ENLT end / go to UTM Waypoint: N 4094343 / E 579652, then continue 160 meters to the last trail waypoint.

- TOT (7 plots)- This transect follows the Twin Oaks Trail through a small grassland dominated by Coyote brush (*Baccharus pilularis*). From the Wilder Ranch SP entrance, drive into the park, past the fee kiosk and straight downhill to the Cultural Center. Turn left and pass through the buildings, keeping left. Pass under the freeway and veer left at the fork, until the road switches back to the left. Follow the road up the hill for about 4 km, before it reaches a junction with a paved road. About 100 meters before that junction, the road makes a sharp left turn by a small grove of oaks. The Twin Oak Trail sign is there. Park and take the trail southeast.
  TOT start / UTM Waypoint: N 4093873 / E 580230
  TOT end / UTM Waypoint: N 4093589 / E 580720
- EULT (3 plots)- Eucalyptus Loop Trail is followed as a transect from its west end. To get there, enter the park through the Twin Gates entrance (off Empire Grade Road) and follow the dirt road to the first fork. Take the right fork (Chinquapin Trail) and stay on this road until reaching the eucalyptus grove. Turn right and follow for about 1 km until reaching the intersection of the Enchanted Loop Trail. Park and follow the trail south, through a small grassland, and into some woods.
  OCT start / UTM Waypoint: N 4093971 / E 580420 (estimated from Arcview)
  OCT end / UTM Waypoint: N 4093906 / E 580615 (estimated from Arcview)
- LKT (2 plots)- The Lime Kiln trail descends from the old lime kiln ruins to Wilder Creek. To get there, enter the park through the Twin Gates entrance (off Empire Grade Road), and follow the dirt road to the first fork. Take the left fork (Long Meadow Trail) and stay on this road until reaching the Lime Kiln area (4 – 5 km). The starting point to this short transect is about ½ km from the ruins, at a point where a trail joins from the left. Follow the left hand trail to get to the plots.
  LKT start / UTM Waypoint: N 4093776 / E 582360
  LKT end / UTM Waypoint: N 4093761 / E 582445 (estimated from Arcview)
- ELT (1 plot)- This transect was off of Engelsmann Loop Trail. To get there from the Wilder Ranch SP entrance, drive into the park, past the fee kiosk and straight downhill to the Cultural Center. Turn left and pass through the buildings, keeping left. Pass under the freeway and veer left at the fork, following straight. After crossing Peasley Gulch Creek, the road forks. The transect is located along the right fork about 1 km uphill, close to the small ponds on the left.
  ELT start / UTM Waypoint: N 4092162 / E 581889
  ELT end / UTM Waypoint: N 4092235 / E 581945

B.) Feral Pig Monitoring Data- 2001

All monitoring data is contained on the Excel spreadsheet, “Pig Data,” found on the CD accompanying this report. Presence/ absence of pig sign is indicated by T (true)/ F (false). Damage is entered as % total plot area. Presence of plant species are shown by a 1. Copies of the spreadsheet and graphs follow this page.

C.) Data Summary and Analysis

The preliminary study done on the random plot method yielded some information on the ease with which it could be performed (Table 1). The average distance one could walk from the trail into the woods before reaching thick vegetation was about 24 meters, and the average overall accessibility was estimated to be "difficult." The average severity of encountering poison oak was estimated to be "moderate." The range of conditions encountered while attempting woodland plots was wide enough to prevent the method from being done consistently.

A total of 111 plots were monitored once during the season for pig presence, and 50.4% of them had pig sign. Of these, 92 plots were in grassland areas of the park, and 19 were in woodland areas. The locations of plots were widespread, and reflected an array of elevations and spatial breadth. Most of the pig sign appeared to be found in grasslands, as opposed to woodland areas. To test this, a Fisher's Exact test was run on the data, yielding not quite a significant difference ($P=0.08$). See Table 3 for a summary of the data.

In general, the transects with the highest amount of pig activity were located at PG 6, PG 7, ENLT, TOT, PG9a, and PG 9b, with 80-90% of their plots containing pig sign. These sites are located in the central and eastern areas of the park (refer to map, Appendix 2). The total area of these plots is 5400 square meters, and of this, 1230 square meters (22.8%) was rooted by pigs. The three transects with the largest extent of pig damage in relation to their area was PG 9b, ENLT, and TOT, with 35%, 32.8%, and 30.3% of their total plot areas rooted. These three areas are close to each other, in the central area of Wilder Ranch State Park. Overall, pigs damaged 14.6% of the total area of all plots in the park. Elevation did not appear to have any affect on the distribution of pig activity, although most of the recorded activity in spring and summer took place above 120 meters (Table 2).

Thistle (both *Cirsium vulgare* and *Carduus pycnocephalus*) was prevalent in the grasslands. Overall, out of 111 plots (both rooted and non-rooted), 37.8% of them contained some species of thistle. Total grassland plots contained twice the frequency of thistle as woodland plots (42.4% vs. 21.1%). The transects in PG 6, PG 3, and PG 9a had the three highest frequencies of thistle with 90%, 70%, and 60% of their plots containing these exotics. The results of a past study (Ag Commissioner 1990) revealed that pigs had been active in these three areas in 1988. Whether or not there is a direct correlation between pig activity and thistle presence could not be determined by this study alone, although observations would lead one to believe it. Other frequently encountered non-native plant species include *Briza maxima, Vulpia bromoides, Avena sativa, Plantago erecta, Hypochaeris radicata, and Cotoneaster* spp (Table 4).

A couple of plant species were found to be more frequent in areas of high pig activity than low pig activity. The grass *Briza maxima* appeared to be more prevalent in areas where pigs were active. The data was analyzed by Fisher's Exact Test to see if a significant portion of active areas contained this species. A very significant difference was found between plots showing pig activity and those that didn't (two-sided P = 0.007), with *B. maxima* being more frequent in plots showing pig activity (see table 4). One possible explanation is that pigs use this grass as forage, so are attracted to areas where it grows. One pig was witnessed eating *Briza maxima* in August. Also, some of the scat observed in the same area had undigested hulls of *Briza*. In woodland areas, 83.3% of the plots (n=6) with pig activity contained a species of *Quercus*. This is expected, knowing that acorns make up much of their diet. There was not found any other such relationships between plant species and pig activity with the limited amount of data.

Incidental observations were also recorded and are found in table 5. Over half of the observations of feral pigs were in grassland habitats, and usually included one or two adults with several young. Sightings were scattered pretty evenly over the park. A few wallowing sites were found. Incidental observations have been added as a theme to the Arcview project, feralpig.apr.

Table 1: Preliminary Study for Random Plot Method

Location	Distance (m)[1]	Accessibility[2]	Poison Oak[3]	Pig Sign?[4]
Chinquapin (spur trail)	25.8	3.0	3.7	yes (G)
Woodcutter's Trail	25.8	2.6	2.5	no
Lime Kiln Trail	30.4	2.4	2.3	no
Wild Boar Trail	5.9	3.3	3.3	yes (G)
Eucalyptus Loop Trail	34.4	2.6	2.8	yes (G)
Total (all woodland trails)	24.3	2.8	2.6	

[1] mean estimated distance from trail to thick vegetation
[2] mean accessibility rating (for 100 m stretch into woods)
[3] mean severity of poison oak (by estimated denseness)
[4] "was pig sign found along edge of trail?" (G = grassland segment)

Table 2: Pig Distribution by Elevation

elevation range (m)	# plots in range	# plots w/ pig sign	% plots w/ sign	% total plots
61-122	31	16	51.6%	14.4%
122-183	40	18	45%	16.2%
183-244	19	12	63%	10.8%
244-305	21	10	47.6%	9.0%

Table 3: Pig sign, damage, and thistle presence in study plots

study site	n	G/W[1]	% w/ pig sign	% area damaged	% plots w/ thistle	elevation (m)[2]
PG 1	10	G	20	11	10	137-183
PG 2	10	G	10	0.5	30	76-146
PG 3	10	G	10	1.0	70	67-153
PG 6	10	G	80	26	90	76-79
PG 7	10	G	90	24	40	98-162
PG 9a	10	G	80	14	30	213-265
PG 9b	10	G	90	35	60	201-262
PG 10	10	G	20	4.5	10	213-281
TOT	7	G	85.7	30.3	28.6	159-183
ENLT	7	G,W	85.7	32.8	42.8	98-165
WAR	1	W	0	0	0	213-220
BCR	4	W	25	2.5	50	250-265
CNS	3	W	66.7	2.3	33.3	268-293
ENLTW	3	W	0	0	0	98-125
EULT	3	W	0	0	0	165-174
LKT	2	W	0	0	0	165-171
ELT	1	W	100	10	0	82
Total (G)	92	G	54.3	16.6	42.4	
Total (W)	19	W	31.6	1.9	21.1	
Park Total	111	G,W	50.5	14.6	37.8	
Past studies						
1988 Total	21	G,W	62	N/A	N/A	
1990 Total	19	G,W	21	N/A	N/A	

[1](G = Grassland, W = Woodland)
[2](Approximate elevation range of the plots in meters)

Fisher's Exact Test: Is there a difference in frequency of pig activity between grassland and woodland plots?

	Present	Absent	Total
Forest	6 (5%)	13 (12%)	19 (17%)
Grassland	50 (45%)	42 (38%)	92 (83%)
Total	56 (50%)	55 (50%)	111 (100%)

2 sided P = 0.0824; not quite a significant difference

Table 4: Plant composition of study plots (% total plots with presence)

Note: All ferns, vines, and woody plants > 1 meter are recorded as shrubs.

Frequent Grasses (top three frequencies):

PG 1- *Avena sativa* (70%), *Bromus diandrus, Danthonia californica* (30%), *Nassela pulchra* (20%)

PG 2- *Danthonia californica* (80%), *Vulpia bromoides* (60%), *Nassela pulchra* (40%)

PG 3- *Vulpia bromoides* (60%), *Danthonia californica* (40%), *Avena sativa* (40%)

PG 6- *Lolium multiflorum* (50%), *Bromus diandrus* (40%), *Holcus lanatus* (30%)

PG 7- *Briza maxima* (90%), *Danthonia californica* (60%), *Holcus lanatus* (40%)

PG 9a- *Briza maxima* (100%), *Danthonia californica* (90%)

PG 9b- *Briza maxima* (100%), *Nassela pulchra* (90%), *Vulpia bromoides* (20%)

PG 10- *Briza maxima* (100%), *Danthonia californica, Nassela pulchra* (60%), *Vulpia bromoides* (10%)

TOT- *Vulpia bromoides* (85.7%), *Briza maxima* (57%), *Avena sativa* (42.8)

ENLT- *Vulpia bromoides* (80%), *Briza maxima* (60%), *Avena sativa* (40%)

ENLTW- None detected

BCR- *Briza maxima* (100%), *Bromus diandrus* (50%)

CNS- None detected

EULT- None detected

LKT- None detected

ELT- None detected

WAR- None detected

Frequent Forbs (top three frequencies):

PG 1- *Cirsium vulgare, Plantago erecta, Vicia sativa* ssp. *nigra* (10%)

PG 2- *Carduus pycnocephalus, Linum bienne* (20%), *Chlorogalum pomeridianum, Cirsium vulgare, Hypochaeris radicata, Rumex acetosella, Vicia s.* ssp. *nigra* (10%)

PG 3- *Carduus pycnocephalus, Linum bienne* (70%), *Chlorogalum pomeridianum, Plantago erecta, Trifolium angustifolium* (20%), *Baccharis douglasii* (10%)

PG 6- *Carduus pycnocephalus* (80%), *Cirsium vulgare* (70%), *Conium maculatum, Linum bienne, Plantago erecta, Rumex pulcher* (10%)

PG 7- *Plantago erecta* (90%), *Cirsium vulgare* (30%), *Baccharis douglasii, Carduus pycnocephalus, Conium maculatum, Eschscholzia californica, Hypochaeris radicata, Satureja douglasii, Thermoposis macrophylla, Vicia s.* ssp. *nigra* (10%)

PG 9a- *Plantago erecta* (60%), *Cirsium vulgare, Hypochaeris radicata* (30%), *Anagallis arvensis, Linum bienne* (10%)

PG 9b- *Cirsium vulgare* (60%), *Plantago erecta* (50%), *Chlorogalum pomeridianum, Vicia s.* ssp. *nigra* (20%)

PG 10- *Plantago erecta* (100%), *Chlorogalum pomeridianum* (50%), *Cirsium vulgare* (20%)

TOT- *Hypochaeris radicata* (57%), *Cirsium vulgare, Linum bienne, Plantago erecta, Vicia s.* ssp. *nigra* (28.6%)

ENLT- *Cirsium vulgare, Rumex acetosella* (42.6 %), *Lupinus nanus, Plantago erecta* (28.6 %), *Asarum caudatum, Oxalis oregana* (14.3%)
ENLTW- *Oxalis oregana* (100%), *Asarum caudatum* (33.3%)
BCR- *Carduus pycnocephalus, Cirsium vulgare, Rumex acetosella, Vicia s.* ssp. *nigra* (25%)
CNS- *Symphoricarpos albus* (66.7%), *Cirsium vulgare, Dryopteris arguta* (33.3%)
EULT- *Oxalis oregana* (33.3%)
LKT-, *Galium* spp., *Satureja douglasii, Symphoricarpos albus* (50%)
ELT- *Carduus pycnocephalus* (100%)
WAR- None detected

<u>Frequent Shrubs</u> (top three frequencies):
PG 1- *Baccharis pilularis* (10%)
PG 2- *Baccharis pilularis, Toxicodendron diversilobum* (10%)
PG 3- *Rubus ursinus* (10%)
PG 6- *Baccharis pilularis* (20%), *Toxicodendron diversilobum* (10%)
PG 7- *Baccharis pilularis* (30%), *Cotoneaster* spp., *Pteridium aquilinum, Rubus ursinus, Toxicodendron diversilobum* (10%)
PG 9a- *Baccharis pilularis, Pteridium aquilinum* (10%)
PG 9b- *Baccharis pilularis* (70%)
PG 10- *Baccharis pilularis* (20%)
TOT- *Baccharis pilularis* (57%)
ENLT- *Baccharis pilularis, Toxicodendron diversilobum* (28.6%), *Rubus ursinus* (14.3%)
ENLTW- *Polystrichum munitum* (66.7%), *Actaea rubra* (33.3%)
BCR- *Toxicodendron diversilobum* (75%), *Rubus ursinus* (50%), *Baccharis pilularis, Mimulus auranticus, Pteridium aquilinum* (25%)
CNS- *Rubus ursinus* (100%), *Corylus cornuta, Rosa gymnocarpa, Toxicodendron diversilobum* (66.7%), *Lonicera hispidula* (33.3%)
EULT- *Rubus ursinus, Toxicodendron diversilobum* (66.7%), *Polystrichum munitum* (33.3%)
LKT- *Lonicera hispidula* (100%), *Toxicodendron diversilobum* (50%)
ELT- *Rubus ursinus, Toxicodendron diversilobum* (100%)
WAR- *Arctostaphylos tomentosa, Lonicera hispidula, Rubus ursinus* (100%)

<u>Frequent Trees</u> (top three frequencies):
PG 1- None detected
PG 2- None detected
PG 3- None detected
PG 6- None detected
PG 7- *Quercus agrifolia* (10%)
PG 9a- None detected
PG 9b- None detected
PG 10- None detected
TOT- None detected
ENLT- *Quercus agrifolia/ parvula, Quercus wislizenii* (14.3%)

ENLTW- *Lithocarpus densiflorus* (100%)
BCR- *Pseudotsuga menziesii* (75%), *Quercus agrifolia*, *Quercus agrifolia/ parvula* (25%)
CNS- *Pseudotsuga menziesii* (100%), *Quercus agrifolia* (66.7%)
EULT- *Umbellularia californica* (66.7%), *Quercus agrifolia/ parvula*, *Quercus agrifolia*, *Arbutus menziesii* (33.3%)
LKT- *Quercus agrifolia*, *Quercus agrifolia/ parvula* (100%), *Umbellularia californica* (50%)
ELT- *Quercus agrifolia* (100%)
WAR- *Pseudotsuga menziesii*, *Umbellularia californica* (100%)

Fisher's Exact Test: Is there a difference in *Briza maxima* frequency between plots with and without pig activity?

	Briza present	*Briza* absent	Total
Pig activity	31 (34%)	19 (21%)	50 (54%)
No pig activity	14 (15%)	28 (30%)	42 (46%)
Total	45 (49%)	47 (51%)	92 (100%)

2-sided P = 0.007, considered very significant

Table 5: Incidental observations of feral pigs, 2001

Date	Location	Sign	# Adults	# Young	Stock	Habitat	Initials
4-19-01	Lower Wilder Ridge	r				G	CS
4-19-01	Upper PG 3	r				G	CS
4-19-01	Wilder Ridge Loop	r				G	CS
4-19-01	Lower PG 9a	r				G	CS
4-19-01	West ELT (PG 7)	w				G	CS
5-3-01	Lower east ELT		1	6	?	G	TS
5-3-01	Forest plot R48	c				W	TS
5-3-01	NW EULT		1	8	?	G	?
5-28-01	Sand Hills	a,s,t				C	TS
6-1-01	West EULT		2	3		W	KO
6-6-01	Sand Hills	s,t				C	CS
6-7-01	SW ELT		1	2-3	B	W	CS
6-7-01	SW EULT	r				G	CS
6-12-01	BCR, spring	t,w				W	CS
6-12-01	BCR @ Baldwin Ck	c,t,w				R	CS
6-12-01	BCR by trap	r	2	2-4	B	G	CS
6-19-01	Chinquapin (Photo)	r				G	CS
6-27-01	PG 10	t,w				G	CS
7-11-01	NE ELT (PG 7)	a	1			G	CS
7-17-01	Four Mile Produce	t				A	CS
7-18-01	TOT/EULT junction	r	2		D	W	CS
7-18-01	Wild Boar Trail	r				G,C	CS
7-18-01	South EULT	r				G	CS
7-18-01	Chinquapin spur	r				G	CS
7-24-01	South ENLT	r	2-3	3-4	D	G	CS
7-29-01	Lower west ELT	r				G	CS
8-?-01	Chinquapin Trail		8-10	?	?	G	?
8-8-01	Wilder Canyon	c				W	TS
8-9-01	CNS, along trail	r,t,w				R	CS
8-9-01	CNS, creek	t,w				R	CS
8-14-01	PG9b	r	1(1)	1	D	G	CS
8-14-01	SW EULT	r				G	CS
8-15-01	Northeast of Sand Hills	s,t				W	TS
9-9-01	Wilder Creek Estuary	a,c,s,t				G,R	CS
9-20-01	Wild Boar Trail	c,r				C	TS
9-25-01	ENLTW		1	4	?	W	RW

(1) Pig in PG 9b was grazing on *Briza maxima*

Sign: a = audible sounds, c= cover, r = rooting, s = scat, t = tracks, w = wallow
Stock: B=Wild Boar, D=Domestic/ Hybrid
Habitat: A=Ag Field, C=Chaparral, G=Grassland, R=Riparian, W=Woodland

D.) Comparison With Past Study

In 1988 and 1990, Wilder Ranch State Park was monitored for pig activity. These two years represented conditions before and after a drought. In 1988, 21 sites were monitored, that included 7 of the same general areas monitored in 2001. In 1990, 19 of these sites were monitored. The seven sites correspond with this study as follows:

Study Sites 1988/90[1]	Study Sites 2001	Results 1988	Results 1990	Results 2001
B	PG 7	no sign	no sign	sign
E	ELT	no sign	no sign	sign
H	PG 9a	sign	sign	sign
M	PG 6	sign	no sign	sign
O	ENLT	sign	no sign	sign
Q	PG 3	sign	no sign	sign
T	ENLTW	sign	sign	no sign

[1] University of California (1988), Santa Cruz Co. Agricultural Commissioner (1990)

The mean amount of pig activity in Wilder Ranch State Park in 2001 (50.5% of plots) shows a slight drop from the 1988 mean (62% of sites). Because of differences in methods, it is not possible to compare the extent of pig damage between the two time periods.

E.) Conclusion

In terms of the five objectives of the study described in the introduction, the following conclusions can be made, based on one season of study:

1. The greatest indication of pig presence in the park was on the east-central portion, including study sites PG 6, PG 9a & b, ENLT, TOT, and PG 7. In general, though, pigs were found to some extent all over the park.
2. Compared to past non-drought years, pig presence has not declined dramatically at Wilder Ranch State Park.
3. Almost all pig sign found in surveys was rooting damage. Of the six sites with 80% or more plots with pig sign, all but one had 24-35% total plot area damaged.
4. The grass *Briza maxima* is more frequently found in the grassland study plots where pig activity was recorded. In the woodland plots, *Quercus agrifolia* was the most frequently found species where pig activity was recorded.
5. The transect method used in grassland areas proved to be the most efficient and provided the most accurate data. The random plot method used in the woodlands proved to be problematic, inconsistent, and yields inaccurate data if used for statistical purposes.

IV.) Data Management

Copies of the original field data are stored in two separate locations. Field data from the study was then transferred from field data sheets to an Excel format, labeled "Pig Data." All GPS waypoints were loaded from the field GPS unit onto the software GPS Pathfinder Office, differentially corrected and transferred to Arcview as shapefiles. An Arcview project was then made. Maps were generated, with all plot locations.

A CD accompanies this report with the following contents:

- An electronic copy of this report
- Copy of the Excel database
- Folder of Internet references
- Folder containing the Arcview project, feralpig.apr, and associated files. This includes a GIS-generated map, showing all study plot locations, alien plant locations, incidental observations, and watershed compartments. Arcview 3.2 is needed to open this map.
- Folder of photograph files (.jpeg files)

V.) Future Monitoring Plan

The following recommendations are being made for monitoring of feral pigs in Wilder Ranch State Park:

1. Monitor only the grasslands, using the transect method. The entire park can be monitored in 7 days by one person, two people could probably do the job in 4 days. The reasons this is the most effective way, is that the pigs utilize the grasslands more in the late winter and spring, pig sign is much easier to see on the grasslands, and the transects are completed more quickly. This data can be used for statistical purposes. Each new survey should be a separate transect.
2. For small grasslands, it is recommended to perform surveys with 500 m transects. More than one transect can be placed in parallel, with transects no closer than 100 m. These results can be added to the database from the larger grasslands.
3. Monitoring the woodland areas by random plot method is not recommended.
4. Pig presence should be monitored at least once per year. The best time to monitor pig activity by the transect method is summer, especially in July. By then, most of the pigs have stopped rooting in the grasslands. Two surveys per year, one in early spring and one in mid-summer, will give a better picture of pig presence in a given year, if there is enough time to do the work.
5. The plant survey that accompanied the pig survey is optional, but it is recommended. Using the CNPS Rapid Assessment protocol will help align the data with other monitoring efforts in the park. If there is interest in monitoring what plant species revegetate rooted areas, see Peter Kotanen's study (1995) for a useful methodology.
6. Since it is also important to survey pig activity in woodlands as well, it is

recommended to establish several survey trails, of equal lengths (i.e., a 1 km segment), to be walked every three to six months. The trails should represent a wide area of the park (i.e., Woodcutter's Trail, Old Cabin Trail, Wagonwheel Trail, & Enchanted Loop Trail). Pig sign could be recorded, described, and points put on a GIS map to monitor locations. This survey could be done in a day by one person.

7. It is also recommended that along with woodland trails, known or potential wallowing sites should be visited 2-4 times per year and surveyed for pig sign. Any permanent water (seeps, springs, or puddles) is a potential wallow. This is a reliable way to detect even a small population of pigs (Barrett, pers. com. 2002).
8. Sightings by park visitors should be recorded along with locations.

VI.) <u>References</u>

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Appendix 1

Contacts

- Reginald Barrett, Ph.D.
  Professor of Wildlife Biology and Management
  UC Berkeley
  (510) 642-7261
  rbarrett@nature.berkeley.edu
  Dr. Barrett has done much research on feral pigs, with many published articles. He is a good source of information on research methods and biology of feral pigs.

- Emily Roberson
  Sr. Land Management Analyst
  California Native Plant Society
  (415) 970-0394
  emilyr@cnps.org
  California Native Plant Society has made known their concern over the feral pig problem in California. Emily is well networked and knows much about where feral pigs are a problem.

- Dave Tibor
  Rare Plant Botanist
  California Native Plant Society
  dtibor@cnps.org
  Dave may be a good source of information about where populations of rare plants occur in the state, and help identify any potential problems caused by feral pigs.

- Dirk Van Vuren, Ph.D.
  Professor of Wildlife Biology
  UC Davis
  (530) 752- 4181
  dvanvuren@ucdavis.edu
  Dr. Van Vuren has participated in several published studies with feral pigs.

- John Waithman
  Biologist
  California Dept. of Fish and Game
  Region 3, Yountville, CA
  (707) 944-5528 (Wildlife Management)
  jwaithma@dfg.ca.gov
  John has published some studies on feral pigs in California and runs the Wild Pig program for DFG.

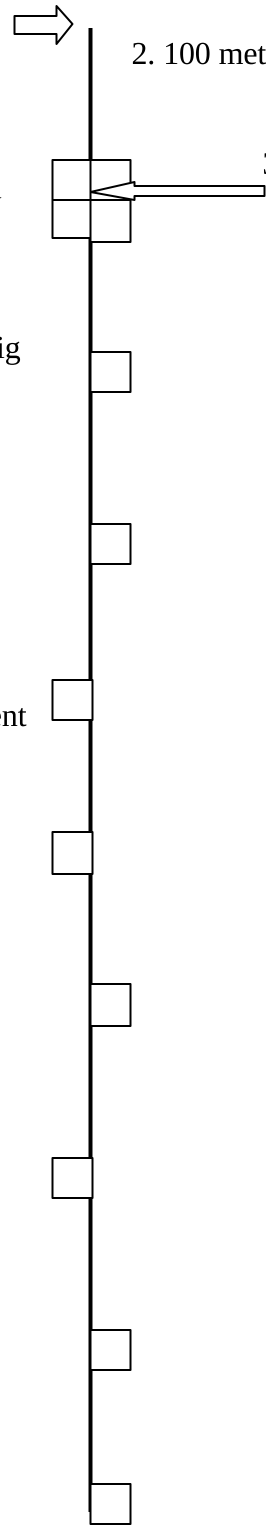
Appendix 2

Graphics

<u>Figure 1: Example of 1 km transect</u>

1. Compass bearing is taken, establishing direction of transect

Random starting point



2. 100 meters is stepped off with calibrated steps

3. Waypoint is taken at the 100 m mark

4. Plot placement is randomly chosen from 4 possibilities

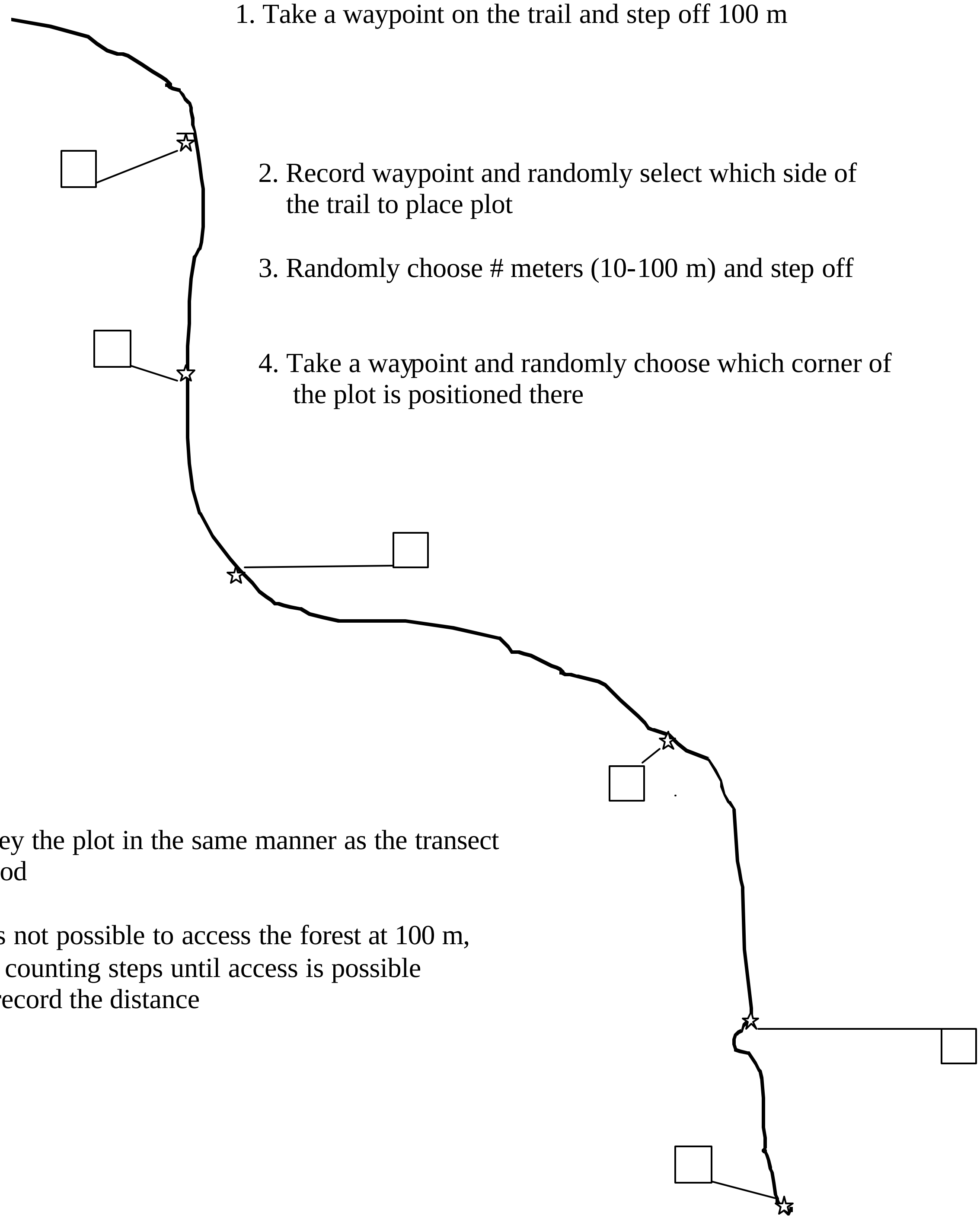
5. Each plot is surveyed for pig sign, % area damaged, and abundant plant species

6. Pig sign includes rooting, tracks, scat, wallows, and cover

7. If the transects are permanent stake each plot at the four corners

8. If more than one transect is done, no plot should be less than 100 m apart

Figure 2: Example of Random Plot Method



Start

1. Take a waypoint on the trail and step off 100 m

2. Record waypoint and randomly select which side of the trail to place plot

3. Randomly choose # meters (10-100 m) and step off

4. Take a waypoint and randomly choose which corner of the plot is positioned there

5. Survey the plot in the same manner as the transect method

6. If it's not possible to access the forest at 100 m, keep counting steps until access is possible and record the distance

Appendix 3

Protocols & Pertinent Studies

Appendix 4

Equipment