

Using Survey Data to Monitor Population Status and Develop Habitat
Models for Fishers and other Mesocarnivores

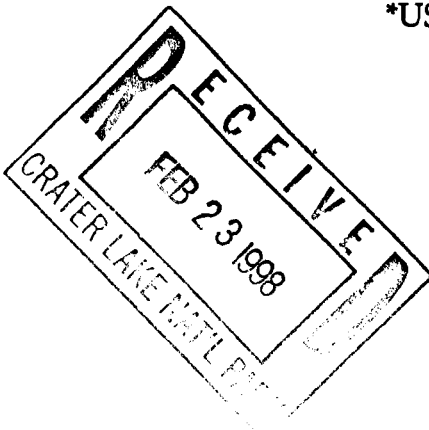
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SUMMARY[†]

We report the results of the first year (1996) of two years of systematic mesocarnivore surveys in the Klamath and the Central Sierra regions of California. The research has two main objectives: (1) improving parameter estimates for a simulation model (Zielinski and Stauffer 1996) used to plan a statewide monitoring program for fishers, and (2) developing multi-scale habitat models for fisher, and for other species of mesocarnivores. Each sample unit was composed of 6 track plate stations, half enclosed in wood and half in plastic. Sample units were positioned on every other National Forest Inventory grid location, placing the centers of the units at least 10.8 km apart. Nine species of carnivores were detected at the 40 sample units (240 stations) surveyed on the Klamath study area and 10 species were detected at the 35 sample units (210 stations) surveyed on the Central Sierra study area. Most species were detected more frequently on the Klamath than the Central Sierra area. Fishers were detected at 67.5% of the sample units on the Klamath area but were not detected at any of the stations in the Central Sierra area. Using these new numbers to improve estimates in the simulator, the statistical power to detect a 20% decrease in a statewide index of fisher occurrence dropped from 74 to 66, (for the five strata condition), and from 80 to 79 (10 strata). The fisher habitat model was developed for the Klamath region only, using 1991-1995 survey data, and was validated using the results of the first year of our systematic surveys. Structural and compositional information about the habitat was collected at each survey station (plot data) and from attributes of an unsupervised classification of Landsat imagery for a 2,380 km² area (landscape data). The final multiple logistic habitat model for fishers included the "moving average" (each pixel represented by the average of the 10 km² circle on which it is centered) of the following variables: Vegetation Density (~canopy closure), Tree Size, and Percent Conifer. Also included were Annual Precipitation and UTM Northing and the following interaction terms: Density x Percent Conifer and Tree Size x Annual Precipitation. This model resulted in a correct classification of 80%. The 1996 surveys, designed to validate the model, resulted in correctly classifying 75% of the sites. Vegetation data collected at the Klamath stations confirm the landscape predictions in most cases, but add little explanatory power to the habitat model. Gray fox, ringtail and spotted skunk detections on the Klamath area differed from fisher in that the former group was negatively associated with conifer cover and were each detected at significantly lower elevations than where they were absent. Additional analysis of the habitat associations of fishers, and other carnivores, will be conducted after the 1997 field season where we intend to sample an additional 15-20 sample units in each study area.

[†]The work described herein is preliminary and portions are in partial fulfillment of graduate degrees for Mr. Carroll and Ms. Campbell, therefore we ask that the data not be cited without our permission.

INTRODUCTION

The management of western forests requires that we understand the effects of timber harvest - and other disturbances - on landscape features that are important to wildlife. To accomplish this we can either (1) model the relationship between habitat and animal populations and predict change in populations on the basis of change in habitat, or (2) directly monitor the distribution and abundance of species that are considered sensitive to forest management practices. The former approach is potentially more cost-effective, but assumes that we need only information about habitat to predict the distribution and abundance of animals. The latter has the benefit of relying on few assumptions but the disadvantage of requiring expensive field surveys. Here we report the first of two years of progress toward the development of both approaches for a select group of forest mammals, the intermediate-sized mammalian carnivores, or "mesocarnivores" (Soule et al. 1988, Buskirk in press). Special emphasis is given to the fisher (Martes pennanti), a species that is particularly vulnerable to change in forest habitat (Rosenberg and Raphael 1986, Powell and Zielinski 1994).

As timber harvest, residential development, roads and fire alter forested landscapes and remove mature forest cover, the populations of carnivores are especially vulnerable because their low densities and relatively low recolonization rates render their populations vulnerable to isolation. Little is known about the distribution or ecology of many mesocarnivores that occur in the forests of the western United States, even less so about their responses to alteration in forest structure and composition. Of particular concern are the species that appear to be most closely associated with late-successional coniferous forests; the fisher and American marten (M. americana) (Buskirk and Powell 1994, Buskirk and Ruggiero 1994, Powell and Zielinski 1994). Reliable habitat models are lacking for both species in the western US. In addition, no state or federal agency has implemented a monitoring program for populations that are protected from trapping. For carnivores to be fully integrated in ecosystem conservation plans, additional research is necessary to achieve one, if not both, of these goals.

Monitoring Population Status

In 1994, work began on an approach to monitor change in California fisher or marten populations. The result was a simulation model that estimated the statistical power of various sampling designs to detect statewide declines in indices of fisher or marten populations (Zielinski and Stauffer 1996). We proposed a stratified design with strata

sampled for proportions of occurrence at discrete points in time. The model output included sensitivity analyses, where several of the parameters were varied over their expected ranges. However, the most relevant runs were those where it was necessary to estimate the proportion of sampling units that would receive a fisher detection for each of five or 10 geographic strata in the California fisher range, if the sampling were conducted today. The more realistic these estimates, the more precisely we would be able to determine the sampling effort necessary to detect specified declines in the population index. Initially, the results of surveys associated with proposed timber harvests were used to arrive at these estimates, but these surveys were designed for different objectives and their geographic distribution was inconsistent with the strata we had proposed. Consequently, these estimates were wild guesses. Therefore, the initial reason for undertaking the work reported here was to conduct pilot sampling, according to the design proposed in Zielinski and Stauffer (1996), to generate the most realistic estimates of the proportion of sampling units that would receive detections in two of the five regional strata in California. The "Klamath" and "Central Sierra Nevada" strata (Zielinski and Stauffer 1996) were chosen as study areas for this work because they were where we expected the abundance of fishers to be high and low, respectively, and would provide bounds on the range of our proportion estimates.

Modeling Habitat

Although the research began with the primary goal of refining parameters for the monitoring approach, we realized that these same data would be useful as a means of developing a multiscale landscape habitat model for fishers, and any other species that was frequently detected. The availability of remote sensing imagery for the Klamath region (California Dept. of Forestry and Fire Protection 1993) and the Stanislaus and Eldorado National Forests (USFS Remote Sensing Laboratory, Sacramento, CA) provided digital maps with vegetation information necessary to begin habitat modeling. Because the source of animal location data we planned to collect was from track plates we realized that we would be unable to include resting habitat in the model. However, this information can be included later when the results of nearby studies of fisher resting habitat are complete (Zielinski et al. 1995, Zielinski et al. 1997, R. Golightly, pers. comm.).

The quality of habitat, by itself, cannot explain all the variation in the occurrence or abundance of a species (e.g. Lancia et al. 1982, Irwin and Cook 1985, Morrison et al. 1992). Attributes of vegetation will not correspond completely with the presence, the density, or the viability of a species, a conclusion that has led to habitat models with less

than satisfactory results (see comments in: Best and Stauffer 1986, Chalk 1986, Dedon et al. 1986, Laymon and Barrett 1986, Van Horne 1986; Weins 1989). Although much of the failure is due to the difficulty of analyzing environmental variation from the perspective of the organism (Kotliar and Wiens 1990, Pearson et al. 1996), some can be attributed to the failure to consider habitat scale. Some models exclude important scales of analysis and others apply the results at scales other than that at which the data were collected (Hamel et al. 1986, Irwin and Cook 1985, Morrison et al. 1992, Raphael and Marcot 1986, Rotenberry 1986). The recognition of the influence of multiple scales on habitat selection has led to a renaissance of wildlife habitat modeling at large scales, with promising results (e.g. Baker et al. 1995, Coker and Capen 1995, Mills et al. 1993, Mladenoff et al. 1995, Pedlar et al. 1997, Periera and Itami 1991, Raphael et al. 1995, Ramsey et al. 1994). Although much has been written about the sensitivity of forest carnivores to landscape fragmentation, almost all (see for exceptions Hargis et al. in press, Rosenberg and Raphael 1986) is based on extrapolation from habitat selection at the within-home range scale. Including landscape scale in habitat investigations is considered key to the success of efforts to conserve fishers, and other forest carnivores (Ruggiero et al. 1994). Habitat models that include the landscape scale can be important learning tools - and can be predictive - if attention is paid to validating assumptions about the relationship between vegetation structure and species viability.

The institutional habitat models available for fishers (i.e. Habitat Suitability Index [HSI] of the USFWS [Allen 1983]; California Wildlife Habitat Relationship [CWHHR] models [Mayer and Laudenslayer 1988, Verner and Boss 1980]) were developed primarily to create liberal lists of species predicted to occur in areas where management activity was planned. Because they are created using information from the literature, include only stand-level predictor variables, and do not assess habitat dispersion they are less likely to predict the occurrence or abundance of fishers than statistical habitat models built using regional data collected with multiple scales in mind. We propose a new fisher model for northwestern California, using probability sampling to validate a statistical model.

In the Klamath study area, previous Forest Service surveys indicated that fishers would be quite common (Zielinski et al. 1996) so we expected to collect sufficient new data to test and refine a multi-scale fisher habitat model. We hypothesized that fisher distribution would be influenced by processes operating at various spatial scales. At the patch level, these might include foraging site selection and denning and resting site

selection. At the landscape level, we might see the effects of home range selection by dispersing individuals and source/sink effects. At the regional level, processes might include source/sink and metapopulation dynamics, regional variation in forest composition due to climate, and regional patterns in land use. A graduate research project was developed (C. Carroll, Oregon State University, submitted) with the following objectives:

- (1) Predict fisher distribution in unsurveyed areas.
- (2) Analyze the regional distribution to identify potential reasons for concern about population viability.
- (3) Generate hypotheses as to mechanisms controlling habitat selection and the scales at which they operate.
- (4) Develop models and modeling techniques that can be applied to other regions.

The initial model was built using Forest Service survey data collected from 1989-1994 in northwestern California and then tested using systematic survey data collected from the Klamath study area during the current research study. This analysis relates survey results to various scales of vegetation information to predict the occurrence and distribution of fishers in forests of northwestern California. Because we did not expect to detect fishers frequently enough in the Central Sierra study area to model their habitat, we plan to model the habitat used by gray foxes (*Urocyon cinereoargenteus*). Gray foxes co-occur with fishers and the two species may compete for resources. Foxes achieve higher densities than fishers, are expected to have similar diet, and can transmit fatal disease to mustelids (i.e. canine distemper). Comparing gray fox relative abundance and habitat in the Central Sierra, where fishers are rare, with that in the Klamath, where fishers are common, may help us evaluate the effect of foxes on the recovery of the fisher population in the Sierra Nevada. This hypothesis is central to a second graduate research project associated with the study (L. Campbell, University of California-Davis, in prep.).

Collateral Objectives

Besides the monitoring and modeling goals, there are two incidental objectives for the research we have undertaken. The first is related to management changes imposed by the Northwest Forest Plan (NFP; USDA and USDI 1994), which applies to public land in the Klamath study area. Because of the extensive nature of our sampling (10 km between the centers of adjacent sample units; see Methods, below) we collect verifiable

information on the occurrence of fishers and other carnivores over a large area (approximately 2,400 km² in the Klamath area and 2,700 km² in the Central Sierra Nevada). These field data will be made available to agency biologists to be used in analyses of land-disturbing projects, including Watershed Analyses prescribed by the NFP. Furthermore, under the NFP, surveys for fishers and martens are considered unnecessary, either at proposed timber harvest sites or more generally throughout the region, because it is assumed that Late-Seral Reserves (LSRs) will adequately protect their habitat and maintain their populations. The detections of fishers in the Klamath study area will be related to the distribution of LSRs to test the hypothesis that fishers are more frequently detected in the areas designated for their conservation.

The second incidental objective of the survey work was to investigate how survey protocols for other species could be combined with track plate surveys for mesocarnivores. To date we have adapted a goshawk (*Accipiter gentilis*) survey protocol (Goshawk Working Group 1995) to detect goshawks and other species of raptors at the mesocarnivore survey sites. Surveys for additional wildlife species will be considered for the upcoming 1997 continuation of our field work.

STUDY AREAS

Klamath

The Klamath study area encompasses the region with the most abundant fisher population in California, and probably in the western U.S. The majority of the area is comprised of public forest lands administered by three National Forests, the Six Rivers, Klamath and Shasta-Trinity (Fig. 1). The "Klamath region" analyzed in the fisher habitat model covers about 27,460 km² (10,600 mi²) of public and private lands. The area surveyed in 1996 covers approximately 2,380 km² (920 mi²), or about 9% of the total region and 14% of the total Forest Service land. Elevation in the survey area ranges from about 122 m (400 feet) along the Klamath River to 2,641 m (8,663 feet) at the summit of Thompson Peak in the Trinity Alps. Survey station elevations ranged from 122 m to 1,890 m (400 - 6,200 feet).

The Klamath region of southwest Oregon and northwest California lies at the junction of several biogeographic provinces. Its high plant diversity (3500 taxa, 280 endemic) has been attributed to its "central" location at the hub of several mountain ranges, each with its characteristic forest communities (Whittaker 1961). High topographic, climatic, and

edaphic diversity lead to steep environmental gradients that bring together forest types that elsewhere are widely separated. The topography of the survey area is dominated by the valleys of three rivers, the Klamath, Trinity, and the Salmon, and their numerous tributaries. Much of the higher elevations lie in four protected areas, the Trinity Alps, Marble Mountains, the Siskiyou, and the Russian Wildernesses. The vegetation is influenced by the diversity of topography and soils, as well as by a natural disturbance regime dominated by fire. Large areas of the survey area burned in 1977 and 1987, particularly in the Salmon River basin.

The Douglas-fir type is the most extensive forest community in the Klamath region. The Douglas-fir/mixed conifer type is distinguished from the Douglas-fir/mixed evergreen type which contains a greater hardwood component. Douglas-fir (Pseudotsuga menziesii) is also an important member of neighboring forest types. Up slope it grades into the white fir (Abies concolor) forests and other high elevation types that have little hardwood component. To the east it grades into forests dominated by ponderosa pine (Pinus ponderosa) and gray pine (P. sabiniana). These forests also have a stronger component of deciduous oaks such as Oregon white oak (Quercus garryana) and black oak (Q. kelloggii). To the west it becomes a member of the redwood (Sequoia sempervirens) /western hemlock (Tsuga heterophylla) forest. The redwood forest is often part of a landscape mosaic with patches of oak woodlands.

Average precipitation is highest near the coast in the northwest corner of the region (about 300 cm /year). It decreases sharply eastward and less strongly southward, reaching a minimum of around 50 cm in the southeast corner of the region (Whittaker 1961). Heaviest rainfall occurs in the winter months.

Due to the fact that over 95% of the area is in public ownership, human population density is low and there are few paved roads. The survey area is bisected by three state highways (299, 3, and 96). Willow Creek is the only town with more than 1000 people in the survey area.

Central Sierra Nevada

The Central Sierra Nevada study area is bounded by the South Fork of the Merced River and Middle Fork of the American River. The study area encompasses parts of seven counties: Alpine, Amador, Calaveras, El Dorado, Mariposa, Placer, and Tuolumne. Surveys in 1996 covered the southern portion of this area and included the Stanislaus

National Forest, Calaveras Big Tree State Park, and portions of Georgia-Pacific timber company land (Fig. 2). Areas surveyed cover approximately 1,070 mi² (2,782 km²) of public and private lands. Survey locations ranged from 2,200 to 7,600 feet (671 to 2,317 m) elevation.

Five major rivers drain through the Stanislaus National Forest lands (Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced) contributing to the considerable topographic relief in this area. The types of vegetation are shaped by the variation in topography, soil type, and fire. Significant acreage in the survey area burned in 1987 (120,000 acres; 480 km²), portions of which burned again in 1990 (12,000 acres; 48 km²), and in 1996 (> 60,00 acres; 240 km²) shortly after the conclusion of our surveys. Chaparral is common at the low elevations and at various locations following fire. Oak woodland (e.g. Quercus douglasi, Q. lobata), the lowest elevation forest type, is replaced with increasing elevation by the following types: ponderosa pine, mixed conifer (primarily Douglas fir, white fir, incense cedar [Calocedrus decurrens], sugar pine [Pinus lambertiana]), red fir (Abies magnifica) and lodgepole pine (Pinus contorta). The ponderosa pine and mixed conifer types are characterized by a prominent hardwood component usually represented by black oak and canyon live oak (Q. chrysolepis). A history of widespread timber harvest, beginning with the gold mining era and continuing to the present, has eliminated many of the old-growth stands by clearcutting, and many of the largest conifers in remaining stands by individual tree selection (McKelvey and Johnston 1992).

Unlike the Klamath study area, the central Sierra Nevada has been significantly affected by the expansion of human populations. There has been a tremendous increase in the number of people making their home in the Sierra Nevada. Between 1970 and 1990, human populations in the Sierra Nevada doubled to 650,000; officials predict this number to triple by 2040 (SNEP 1996). Forty percent of this population growth occurred in El Dorado, Placer and Nevada counties (SNEP 1996).

FIELD METHODS

Mesocarnivore survey methods

Survey design was generally consistent with the approach described in Zielinski and Stauffer (1996), where each sampling unit was comprised of six enclosed track plate stations (Fowler and Golightly 1991, Zielinski 1995). Sampling was systematic, with each

sampling unit centered at intersections of a grid with approximately 10 km spacing. This distance was set by the need to fulfill the assumption of spatial independence for monitoring fishers, the species with the largest home range. We chose to align our sampling units with the grid of National Forest Inventory (Thornton et al. 1994, Stevens 1994) vegetation sampling points. Although vegetation sampling has not been completed at these sites within our study areas, we anticipated that detailed and geographically referenced vegetation information would be forthcoming and would complement the data that we would be collecting. NFI grid points are separated by about 5.4 km so that choosing every other point produced locations that were at least 10.8 km apart (Fig. 1, 2). Because of safety concerns, a few points (< 5) had to be relocated. Because our was a probability-based sample (Stevens 1994), our surveys differ from most others in that they are not established along roads. We centered sampling units where the grid location fell, used roads to get as close to the stations as was possible, and hiked the remainder of the distance to the NFI point. Consequently, inference of our results is not limited only to areas close to roads.

The six track plate enclosures were positioned at each sampling unit as follows: a center box was placed as close to the NFI point as was possible and the others were positioned equidistantly around the circumference of a circle with a 0.5 km radius (Fig. 3). Traditional track plate enclosures are plywood, are relatively heavy, and can be burdensome to pack to remote sites. Therefore, we tested the use of a much lighter, plastic enclosure (L. Chow, pers. comm., Zielinski 1995) modified to increase the strength of the plastic (Foresman and Pearson 1995). This reinforcement permitted us to continue to secure and camouflage the enclosures with heavy woody debris. Because this did not always result in a set that prohibited entry from the rear (even though the units were backed against a log or tree) we added a hardware-cloth back to reduce the possibility that bait was removed without a detection. To test the effectiveness of the plastic enclosures at detecting fishers, and other carnivores, half of the track plate stations in each sampling unit were enclosed in wood and the other half in plastic.

Stations were checked and rebaited with chicken parts every other day for 16 days (eight checks). A commercial trapping lure was applied twice at the Central Sierra study area; once at station establishment and again on the fourth visit. Lure was applied in the Klamath study area only to sample units that had not detected a fisher at any of the stations by the fourth visit. This was a compromise between the dual objectives of maximizing the number of sample units with a detection (for population monitoring)

and minimizing the distance that carnivores are drawn to the station (for habitat modeling).

In the Central Sierra area only, two detection methods were used in addition to the enclosed track plates: open plates and remotely-triggered cameras. Open track plates were constructed and operated as described in Zielinski (1995) and one was placed in close proximity to the enclosed track plates at stations 3 and 6, the western-most and eastern-most stations in the sample unit (Fig. 3). The camera systems were single-sensor Trailmaster TM 1500s, as described in Kucera et al. (1995). Cameras were placed at the track plate station that provided the appropriate configuration of trees for camera set up (Kucera et al. 1995). The camera deployment was modified from Kucera et al. (1995) in that no bait was used, resulting in an essentially passive system. Only animals that interrupted the infrared beam, set approximately one foot above ground-level, would activate the camera. We modified the protocol to prevent the presence of the cameras from affecting detections at the track plates. The purpose of these added methods was to improve the chances of detecting species which would not enter an enclosed track plate box, either due to wariness or body size.

Goshawk survey methods

The standard goshawk survey protocol (U.S. Forest Service 1992, Goshawk Working Group 1995) calls for broadcast calls via a tape play-back system every 320 meters along parallel transects 180-275 meters apart. Conforming to this protocol would have required an additional three hours at each sample unit, so we decided instead to broadcast calls only from the six track plate stations locations in each sample unit.

The standard goshawk protocol also requires two broadcast surveys per year at each station, one occurring during the nestling period (June 1 - July 15) and a second one, at least 14 days from the first survey, occurring during the post-fledging period (July 16 - August 31). Again, to minimize conflict with the track plate study we altered the protocol so that both surveys at a station were conducted during the 16 day period we would normally be checking the track plates, once on the fourth check and then again at the last (eighth) check. The "alarm call" was broadcast during the nestling period and the "wailing call" during the post-fledging period for 10 seconds in each cardinal direction. Two surveyors listened and searched for responses by any raptors for 30 seconds after

each broadcast call before broadcasting in another direction. Although nest searches are recommended after a goshawk detection, we did not have sufficient funds to conduct this activity.

Vegetation sampling at survey stations

We collected plot-level vegetation data at each track plate station so as to contrast landscape and patch-level associations. Significant differences across sample units may indicate landscape level associations whereas significant differences among stations in occupied sample units that either did, or did not, receive a detection may indicate patch-level association. Each track plate station was the center of a plot to sample vegetation. Basal area was estimated on a variable radius plot using prism sampling. The diameter, height and condition class of each of the trees counted as "in" was recorded. The number of logs and the canopy closure at the site were estimated using two, perpendicular, 25-m transects centered on the track plate. Logs that intersected the transect were tallied into four, maximum-diameter categories (15-30, 31-60, 61-90, and >91 cm). Canopy closure was measured using a densiometer at the four cardinal directions at the plot center and again at each of the four termini of the transects. Ocular estimates were made of tree and shrub cover by species, of the CWHR type, size class and canopy closure class, and of the Potential Natural Vegetation type (Forest Service, Pacific Southwest Region, Ecology Program classification). In the Klamath area, the distance of each station to nearest water, road and logged area were also noted. The geographic coordinates of station location were recorded either by GPS or by visual referencing to a digital ortho quadrangle map.

GIS METHODS

Klamath

A variety of data sources were available for GIS analysis of the Klamath data. These included two vegetation layers, road data, and hydrologic (stream) data. One of the vegetation layers available was the Land Management Plan (LMP) data developed by individual National Forests from timber type records as part of the forest planning process, and later standardized for use in the development of the Northwest Forest Plan. Because this layer included only Forest Service land we primarily used a second layer developed as part of the Timberland Task Force (TTF) study (California Department of Forestry and Fire Protection 1993). This is based on an unsupervised classification of Landsat Thematic Mapper (TM) imagery combined with

"groundtruthing" of vegetation attributes and is a seamless coverage from the Oregon border south to San Francisco and east to Interstate 5. The classification includes both continuous (e.g. Quadratic Mean DBH) and categorical (CWHR classes) vegetation attributes. The classification accuracy was estimated at 60-80% for each CWHR class attribute, based on validation plots. Its intended use is limited to regional and landscape level analysis such as performed here, rather than project level analysis.

Central Sierra Nevada

The GIS for the Sierra Nevada study area has not been developed to the degree it has in the Klamath. Currently we have available a base map of the boundary of the Stanislaus and Eldorado National Forests and other nearby administrative land units, a digital elevation layer, a road layer, a hydrology layer and a vegetation layer which was created using 1991 remote sensing data.

GIS vegetation layers derived from satellite imagery have several advantages and limitations when compared to traditional vegetation maps based on ground surveys. The advantages include complete coverage of multiple ownerships, standardized and replicable classification techniques, and current and updatable mapping that allows multi-temporal analyses. The limitations include the fact that these layers are more appropriate for landscape and regional level than for patch-level analysis, and attempts to extract more than a few size or closure classes or floristic (species) differences will seriously reduce accuracy (Cohen et. al. 1995). It is for this reason we used plot-level vegetation sampling in conjunction with GIS analysis.

Habitat Modeling Methods

Klamath

The data used to build the fisher habitat model were 682 locations surveyed during the period 1991-1995 by Forest Service and Hoopa Indian Reservation biologists, primarily as part of project-level planning. We refer to the use of these data to create the model as the "retrospective analysis". Survey methods were either sooted track plate or remote camera station. Analysis of the effect of survey duration showed that the effect of survey duration was only evident in surveys of less than 12 days duration (Carroll, submitted), so these surveys were excluded. In addition, season of survey was dropped from consideration when it was demonstrated to have little effect on the fit of

multivariate models, even though detections appeared to be less common during mid-summer.

The clumped distribution of the survey locations would tend to make the model primarily a characterization of areas of high survey effort, such as the Hoopa Reservation and the Six Rivers National Forest fisher study area. Therefore, locations were weighted in the model-fitting process by their distance from neighboring points in the data set using Dirichlet tessellation (Bailey and Gatrell 1995).

The following attributes included in the TTF data layer were analyzed at landscape and patch scales: (1) Canopy Closure, (2) Tree Size Class, (3) Percent Conifer, (4) CWHR Type, (5) CWHR Closure Class. In addition, several attributes from other GIS data sources were evaluated including road density, distance from streams, elevation and precipitation.

Multiple logistic regression (MLR) was chosen as the appropriate method for the statistical analysis due to the binary nature of the response variable (presence/absence). The potential predictor variables derived from the GIS analysis were first assessed for significance in a univariate analysis. Some variables, such as road density, were discarded at this stage due to lack of significance. Other variables, such as patch-level vegetation characteristics and distance to water, were significant in univariate analyses but were discarded in favor of other correlated variables in the course of the multivariate analysis.

The following multiple scale, spatial model was used in the retrospective analysis (Carroll, submitted):

Probability of fisher occurrence = regional variation (trend surface) + landscape (mesoscale) variation + patch level variation + spatially autocorrelated error + uncorrelated site-level variance (e.g. due to sampling error).

Model fitting procedures

Stepwise model fitting was used to help construct a model with good fit to the data. However, the output from the stepwise procedure was assessed for robustness and biological significance to create the model. Although Chi-squared values were produced, the Cp statistic and Bayesian Information Criterion (BIC) (Raftery 1994) were

used to assess the value of including additional variables because they control for reduced degrees of freedom. Generalized Additive Modeling (GAM) (Hastie 1993) was used to assess the need for quadratic terms in the model.

A "moving average" (MA) function in Arc-Info (FOCALMEAN) was used to average TTF vegetation characteristics over a "landscape" whose size was varied during the analysis. The FOCALMEAN function assigns each grid cell the mean value of the cells in a circular "landscape" of a certain radius around it. Two methods were used to test for spatial autocorrelation in the survey data: the Mantel test (Manly 1991) and the CRH method (Clifford et al. 1989). Competing multivariate models were evaluated using the Bayesian Information Criterion (BIC). Validation of MLR model was performed using new data from the systematic surveys conducted during 1996.

PRELIMINARY RESULTS AND DISCUSSION

Mesocarnivore Detections

Detection frequencies

At least nine species were detected at the enclosed plates in the Klamath study area and ten were detected at the Central Sierra study area (Table 1, Fig. 4 -10). We are uncertain about the exact number of species because we cannot distinguish the tracks of the two weasels (Mustela erminea and M. frenata) and of bobcat (Felis rufus) and domestic cat (Felis domesticus). Fishers were the most frequently detected species (excluding bears) in the Klamath area, recorded at 67.5% of the 40 sample units surveyed (Table 1).

Conversely, fishers were not detected at any of the 35 sample units (210 stations) on the Central Sierra area, a region that is within the fisher's historic range. This result supports an earlier conclusion that fishers are either absent from the northern and central Sierra Nevada, or occur there only at very low density (Zielinski et al. 1996).

Gray fox was the most frequently detected species in the Central Sierra study area (51.4% of sample units). Although foxes might be expected to be considerably more common where fishers are absent, the frequency of gray fox detections was not substantially different in the two study areas (51.4% vs. 47.5%). In the Klamath area, where both species were detected, foxes were detected at fewer stations but they were detected at more of the stations in each sample unit and earlier in the survey period than fishers (Table 1), probably due to their smaller home range. Spatial segregation of

foxes and fishers was not indicated: of the 34 sample units where fisher or fox were detected, fisher only were detected at 15, fox only at 7 and fisher and fox at 12.

Of the other commonly detected species, ringtail was detected more than twice as often on the Klamath as on the Central Sierra and spotted skunk was detected at more sample units on the Klamath than the Central Sierra. Marten were detected at very few stations in each area; a result in the Klamath due most likely to the rarity of the Humboldt marten (*M. a. humboldtensis*) (Zielinski and Golightly 1996) and in the Central Sierra to the fact that we did not conduct surveys at sufficiently high elevation to regularly detect marten (martens are most common in the Sierra Nevada above 2200 m). For almost all species that were commonly detected at both areas, each was detected at more sample units and stations in the Klamath than the Central Sierra study area. This may indicate greater productivity in the Klamath than the Sierra Nevada forests, the effect of less human disturbance in the Klamath, or may be due to the larger extent of recently burned region that was surveyed in the Central Sierra than the Klamath. These, and other, possibilities will be evaluated after the plot and remotely sensed vegetation data are analyzed from each study area.

The type of material used to house the track plate did not affect the detection frequency; wood and plastic enclosed plates received similar number of fisher and gray fox detections and did so after similar latencies (Table 2). The lighter weight and portability of the plastic versions compensate in employee morale for their increased costs (\$21.00 vs. \$15.00 per unit) and we recommend they be used instead of plywood.

Latencies to Detection

The mean latency to detection for every commonly detected species, calculated at either the sample unit or the station, was substantially earlier than the 16 day maximum survey duration (Table 1). Latencies to detection did not differ between study area for any commonly detected species (Table 1). On average, fishers were detected by the seventh day (SD = 4.4 days) at any one station in the six-station sample unit, confirming earlier results from similar surveys in California (Zielinski et al. in press). That fishers, and most other species, were first detected before half of the survey period was complete suggests that a shorter survey period may suffice. If population monitoring of one species, say fisher, were the primary concern, considerable resources could be saved if a sample unit were pulled after the first detection. However, pulling the unit at the

first detection reduces the data collected for habitat modeling and also eliminates opportunities to detect other species.

Open plates and cameras used in the Central Sierra Nevada

In addition to the 6 enclosed track plates, two open plates and a 35-mm camera were established at 27 (77%) of the sample units on the Central Sierra area. Cameras were also used at three additional units where open plates were not. Most of the sample units that received a detection of a species at the open plates also received a detection on the enclosed plates, however one species, the coyote (*Canis latrans*), was detected only at the open plates. Four species (bobcat [*Felis rufus*], marten, weasel [*Mustela* sp.] and raccoon [*Procyon lotor*]) were detected at the closed plates but not the open plates. This is probably a reflection of the relatively fewer open plates per sample unit and the low detection rates for these species. Although there were only two open plates in each sample unit, the latency to first detection by sample unit remained about the same, or decreased, when detections at open plates were included. Latency to first detection by station likewise decreased for all species detected at both enclosed and open plates with the exception of spotted skunk which had a lower latency for enclosed plates.

Camera sets detected only three of the 10 species detected at track plates (black bear, fox, spotted skunk), and no species were detected by camera only. This was not entirely surprising given that the sites were not baited and there was only one camera per sample unit. We are considering the use of baited camera stations and increasing the number of cameras per sample unit for 1997 surveys.

Monitoring

The Klamath and Central Sierra surveys were considered to have sampled a representative area of the two geographic strata (as specified by Zielinski and Stauffer 1996) in which they occurred. Thus, in place of the original estimates for these strata, we substituted into the simulator the proportion of sample units in the 1996 surveys that received at least one fisher detection. Because 67.5% of the sample units in the Klamath study area received a fisher detection, 68% was substituted for the 30% estimate used in Zielinski and Stauffer (1996). And, because no fishers were detected in the Central Sierra study area (versus the 5% estimate used in Zielinski and Stauffer [1996]), 1% was used as a surrogate value. Using these new values for two of the five geographic strata, and assuming 115 samples per stratum, the statistical power (arcsine transformed) to detect a 20% decline in the population index was 66, compared to the original value of 74 (Table

3). The change in power is influenced most by the decrease in the proportion estimate for the Central Sierra. This is because the effect of a single proportion estimate is symmetrical around 0.5. Therefore, a decrease from 0.10 to 0.01 in the Central Sierra has more influence on the statewide estimate than a change in the Klamath from 0.30 to 0.68 because the latter pair are about the same amount less than and greater than 0.5, respectively.

In our initial simulations we also estimated sample size and power for a 10-strata condition, where it was assumed that the proportion of occupied sample units in the poor quality habitat in a stratum would be one-half of what it was in the good quality habitat in that same stratum (Zielinski and Stauffer 1996). Using 35% for poor quality habitat in the Klamath and 0.5% for poor quality habitat in the Central Sierra Nevada resulted in a power estimate (transformed) of 79, whereas the original estimate was 80. In this case, the more accurate proportion estimates for the Klamath and Central Sierra strata had little effect on the sample effort necessary to achieve specified statistical power.

If we were interested in detecting either a 20% increase or a 20% decrease (a two-tailed alternative hypothesis) in the index of population change (using the new proportion estimates), the power decreases from 79.2 to 60.0, again assuming 115 samples in each of 10 strata.

Even before the 1996 sampling it was evident that monitoring the status and trend of species as uncommon as fishers would be difficult and expensive. The new estimates for the Klamath and Central Sierra strata do not substantially change that conclusion. Fishers are clearly important species to monitor as they use habitats considered to be at risk, have large home ranges and low population sizes, have relatively low vagility (compared to birds), and likely provide "umbrella" protection for many species that can not be directly monitored. However, it would be economical to include other priority or threatened species in the protocol used to monitor fishers. Goshawks are but one of many species that could be surveyed at the same time the forest carnivore protocol is being conducted. Many other species could be sampled during a typical forest carnivore survey due to the number of times each site is revisited. However, the distance between sample units would need to be re-evaluated in light of whether monitoring, habitat modeling - or both - are goals.

In addition to the necessity of sampling additional species, we also considered alternative approaches to our sample design on the basis of the first year's work. Prime among them is the gradient directed transects, or "gradsect" approach (Gillison and Brewer 1985, Margules and Austin 1995), where surveys are conducted within a wide swath (the gradsect) across the region of greatest environmental heterogeneity. Surveys designed to monitor multiple species using gradsects may be the most efficient means for monitoring and habitat modeling. These and other issues will need to be considered as forest carnivore survey protocols are combined with those of other species, which is likely when the Terrestrial Species Component of the Sierra Nevada Monitoring Plan (USDA 1996) is completed and implemented.

Habitat Modeling: Fisher

[Results are briefly summarized below; a full account of the results and discussion of the fisher habitat model is available in Carlos Carroll's thesis.]

Model Building

In the univariate analysis, Density (~ canopy closure) and QMDBH of hardwoods (derived using moving averages) were the vegetation variables of GIS origin showing the most significance at both patch and landscape scales. Elevation and Annual Precipitation were also significant and there was a significant spatial gradient represented by UTM Northing. UTM Easting and Percent Conifer were marginally significant.

The results of the Mantel tests indicated a strong spatial structure to the environmental data. Matrix distances among the three vegetation attributes (Density, Percent Conifer, and Tree Size) were correlated over space and were intercorrelated even after the effects of geographic distance were removed, demonstrating "non-spatial" and "spatially-structured" variation (Borcard et al. 1992).

The Density MA (canopy closure averaged over a 10 km² area surrounding the location) consistently showed high statistical significance in the multivariate models. This supports previous work indicating that fishers are associated with forests with dense canopy closure. In addition to Density MA, the final multiple logistic model also included Tree Size MA and Percent Conifer MA. General Additive Modeling suggested that UTM Easting and the quadratic UTM Northing explained regional variation at the largest scale. Annual Precipitation, believed to represent the same phenomenon but to

have more biological relevance, was substituted for UTM Easting with little effect on the fit to the data (BIC of -3918 vs. -3951). Finally, two interaction terms were included in the final model: Density MA x Percent Conifer MA and Tree Size MA x Annual Precipitation. Thus the final model was:

$$\text{Logit}(p) = \text{Density MA} + \text{Tree Size MA} + \text{Percent Conifer MA} + \text{Annual Precipitation} + \text{UTMN} + \text{UTMN}^2 + \text{Density MA} \times \text{Percent Conifer MA} + \text{Tree Size MA} \times \text{Annual Precipitation}.$$

Data weighting (Cooks distance) increased the explanatory power of the model substantially, the removal of outliers did so to a lesser extent. The final model had a correct classification of 80.4%. Sites predicted to have detections were more likely to be misclassified than sites predicted to be without detections, a dichotomy that is inherent in modeling rare events (Ramsey et al. 1994). The final model outperformed (using BIC and Cp criteria) the following alternatives: (1) a model that lacked the trend surface component (UTM and Precipitation), (2) a model that calculated MA over areas other than 10 km², (3) models that used only patch (polygon) values, and (4) the California Wildlife Habitat Relationships model for fishers, at every scale.

Model Validation

Validation was conducted using the results of the 1996, systematic surveys and by qualitative comparison with watershed-level results from areas where station-level data were not available (Simpson Timber Company and Shasta-Trinity National Forest; R. Klug, L. Diller, and R. Golightly, unpubl. data). The watershed level data are consistent with the model because the areas used by radio-collared fishers in the Shasta-Trinity study area and the watersheds occupied by fishers in the Simpson timber lands, were predicted to have relatively high probability of fisher occurrence.

As noted above, fishers were detected at 67.5% of the sample units (33.7% of the stations) during the 1996 surveys. When the survey results were compared to the model predictions for each sample unit, 75% of the sample units were correctly classified (Table 4, Fig. 4). This represents a very good fit for landscape models based on retrospective data (Austin and Meyers 1996, Neave et al. 1996). Surprisingly, the model also successfully predicted the variation in fisher detection within sample units, at the station level. The correlation between predicted probability and number of stations in a sample unit with a detection was statistically significant (Pearson's

coefficient = 0.54). Furthermore, two of the sample units with the lowest predicted probability each received a total of one detection at one station during the 16-day sampling period. It appears that the number of stations/sample unit that receive a detection may be a useful index of the quality of fisher habitat and, perhaps, useful at distinguishing the detection of transients from residents.

Comparing the map of predicted probability of fisher occurrence (Fig. 4) with existing reserves (park and wilderness) (Fig. 1) indicates that they provide relatively poor representation of fisher habitat. Although federal parkland (e.g. Redwood National Park) has the highest mean predicted probability, Forest Service wildernesses have the lowest, probably due to their high elevation (Table 5). Late Seral Reserves, designated by the NFP, provide substantially better representation of fisher habitat, which is not surprising given that they were designed to protect another late-seral associated species, the northern spotted owl. However, because the spatial distribution of fishers is more aggregated than the distribution of LSRs, those in the margins of the highest predicted probability of fisher habitat can be expected to receive less use than those close to the center of fisher distribution. Private land has predicted value that is equivalent to LSRs, a conclusion that draws attention to the need for considering all lands as having important value for the conservation of fishers.

Habitat Modeling: Other Mesocarnivores

Preliminary univariate analyses were conducted to evaluate the landscape elements of habitat for gray fox, ringtail, and spotted skunk detected on the Klamath area, using a similar approach as that used for fisher. These three species were negatively associated with Percent Conifer MA; a result not shared with fishers. And unlike fisher, none of the other three species had a significant, positive association with Tree Size MA. Spotted skunk was negatively associated with Tree Size MA, a result that may be due to their abundance in the eastern Klamath area where tree sizes are generally smaller.

Habitat: Plot Data

Klamath Study Area

[To date, plot data have only been summarized for the Klamath Study Area. Plot level data for the Central Sierra study area and comparisons between the two areas will be available in a subsequent report.]

Plot Data: Fishers

Hardwood DBH and Quadratic Mean DBH were higher at stations where fishers were detected, whether analyzed at all stations or only at stations in sample units that received at least one fisher detection (Table 6). When the results at all sample units and stations are considered, fishers were detected at sites that had higher total basal area, higher canopy closure, and lower number of logs. No variables were different when fisher and non-fisher stations were compared within sample units that received at least one fisher detection. This suggests that local, within-sample unit variation had little effect on the probability that individual stations within a sample unit were visited by fishers. Fishers appear to visit all stations with equal probability if they are part of a sampling unit that occurs within a landscape with a high predicted probability.

Plot level results should be interpreted with caution, not only because they are preliminary and the addition of the results from the upcoming 1997 season may change them, but also because we are recording vegetation attributes at locations where a fisher has been attracted to bait. Moreover, the results will probably be different than those collected at rest sites (e.g. Zielinski et al. 1995, Zielinski et al. 1997, Seglund 1995) because habitats used for foraging may be different from those used for resting.

Plot Data: Other Mesocarnivores

Gray fox, ringtail, and spotted skunk were consistently detected at stations that had less conifer cover and larger diameter hardwoods than stations where they were not detected (Table 6). This supports the analysis at the landscape scale, where these same species were negatively associated with Percent Conifer MA. Fishers shared with these three species a positive association with large diameter hardwoods, but unlike these species fishers did not show a negative association with conifer cover. Finally, fox, ringtail and spotted skunk were detected at significantly lower elevations than where they were not detected. These species also differ from fisher in respect to this result as fishers were detected equally across all elevations in the sample area.

Goshawk surveys

Fifteen sample units were surveyed on the Klamath study area and 13 on the Central Sierra study area. During these broadcast surveys one goshawk responded (visual detection) on the Central Sierra area but none were detected on the Klamath area. A Cooper's hawk (*Accipiter cooperii*) responded at a sample unit in the Central Sierra area and two Cooper's hawks responded at different sample units in the Klamath.

Goshawks were sighted on each area incidental to the surveys; twice in the Klamath area and once in the Central Sierra area. Details on all raptor observations are archived with the biologist on the Forest Service districts where they occurred.

FUTURE PLANS

Additional surveys will be conducted during the summer, and possibly fall, of 1997 to increase the sample size for estimating monitoring parameters and to develop more robust habitat models. The Klamath surveys will extend to the north and west so that we better understand habitat value for fishers near the coast and to meet the new objective of understanding the status of the Humboldt marten, whose original range was in the near-coast redwood forests. The Central Sierra surveys will extend to the north with the goal of covering most of the suitable elevations in the Eldorado National Forest. Lori Campbell will extend her experimentation with multiple types of detection methods at each sample unit, including the use of hair snares which may increase the detections of cats. Final analysis will begin in the fall of 1997 and we expect to release a final report by June of 1998. The results of the monitoring aspects will be interpreted in light of integrating this protocol with those of other priority species and with protocols for sampling biodiversity and community metrics (Manley, in prep.). These combined methods will eventually form the basis for the Terrestrial Species Component of the Sierra Nevada Monitoring Plan (USDA 1996).

PAPERS PRESENTED, SUBMITTED, OR IN PREPARATION

- Carroll, C. (submitted). Predicting the distribution of the fisher (Martes pennanti) in Northwestern California, U. S. A. using survey data and GIS modeling. M.S. thesis, Oregon State University, Corvallis, OR.
- Carroll, C. and W. J. Zielinski. Predicting the distribution of the fisher (Martes pennanti) in northwest California using survey data and GIS modeling. Annual Meeting of the Western Section of The Wildlife Society. San Diego, CA. 7 February, 1997.
- Carroll, C. and W. J. Zielinski. Multiscale analysis of the distribution of the fisher (Martes pennanti) using survey data and GIS modeling. Annual Meeting of the Society for Conservation Biology. Victoria, BC. 6 June, 1997.
- Carroll, C. and W. J. Zielinski. (in prep.) Predicting the distribution of the fisher (Martes pennanti) in Northwestern California using survey data and GIS modeling. Conservation Biology.

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Table 1. Characteristics of detections of 11 species of mammals recorded during surveys conducted on the Klamath and the Central Sierra Nevada study areas from 1 June 1996 - 1 November 1996. Klamath study area = 40 sample units, 240 stations, 1920 check occasions; Central Sierra Nevada study area = 35 sample units, 210 stations, 1680 check occasions. MAPE = *Martes pennanti*, MAAM = *Martes americana*, URCI = *Urocyon cinereoargenteus*, SPGR = *Spilogale gracilis*, MEME = *Mephitis mephitis*, BAAS = *Bassariscus astutus*, FESP = *Felis sp.*, PRLO = *Procyon lotor*, MUSP = *Mustela sp.* (weasel), DIVI = *Didephis virginiana*, URAM = *Ursus americanus*.

	MAPE	MAAM	URCI	SPGR	MEME	BAAS	FESP	PRLO	MUSP	DIVI	URAM
Percent of sample units (SU) w/ a detection											
Klamath (%)	67.5	2.5	47.5	47.5	10.0	30.0	2.5	0	12.5	0	90.0
Central Sierra (%)	0	5.7	51.4	28.6	28.6	14.3	5.7	8.6	11.4	14.3	28.6
Percent of stations w/ detection											
Klamath (%)	33.7	0.4	27.9	16.2	2.1	14.6	0.4	0	2.9	0	51.2
Central Sierra (%)	0	2.4	27.1	16.2	11.9	3.8	1.0	1.9	2.4	3.3	7.6
Mean no. stations per SU w/ a detection ¹											
Klamath	3.0	1.0	3.5	2.0	1.2	2.9	1.0	-	1.4	-	3.4
Central Sierra	-	2.5	3.2	3.4	2.5	1.6	1.0	1.3	1.2	1.4	1.6
Mean no. detections per station ¹											
Klamath	2.6	1.0	3.2	2.7	1.2	3.0	3.0	-	1.0	-	2.0
Central Sierra	-	1.0	3.2	2.7	1.8	1.9	1.0	1.0	2.0	1.9	1.1
Mean latency to first detection at a SU (days)											
Klamath	7.0	14.0	3.6	6.6	7.0	5.2	10.0	-	8.0	-	4.0
Central Sierra	-	3.6	8.4	8.8	9.6	9.6	4.0	11.0	4.4	8.8	10.2
Mean latency to first detection at a station (days)											
Klamath	9.4	14.0	6.4	8.4	8.8	7.4	10.0	-	8.8	-	7.2
Central Sierra	-	2.0	6.4	5.6	9.0	10.4	4.0	12	5.0	7.6	7.8

Table 2. Comparison of characteristics of fisher and gray fox detected at stations enclosed in wood versus plastic, 1 June 1996 - 1 November 1996.

	Fisher		Gray Fox	
	Wood	Plastic	Wood	Plastic
Percent of stations w/ a detection				
Klamath	35.0	32.0	32.0	24.0
Central Sierra	--	--	27.6	26.7
Mean detections / station: averaged over all stations				
Klamath	0.90	0.87	0.97	0.81
Central Sierra	--	--	0.91	0.82
Mean detections / station: averaged over stations w/ one or more detections				
Klamath	2.6	2.7	3.0	3.4
Central Sierra	--	--	3.3	3.1
Mean latency to detect (days)				
Klamath	9.0	9.2	6.8	6.1

Table 3. Power estimates to detect a 20% decline in the index of fisher distribution. Original estimates of the proportion of sample units with a fisher detection (in Zielinski and Stauffer [1996]) are compared to the revised estimates using the 1996 survey results. Assumes 115 samples per stratum.

	Original proportion estimates	Revised proportion estimates based on 1996 survey results
5 STRATA		
Klamath	30	68
Klamath-Sierra transition	20	20
Northern Sierra	5	5
Central Sierra	10	1
Southern Sierra	30	30
Power		
untransformed	0.76	0.79
arcsine transformed	0.74	0.66
10 STRATA		
Klamath		
late seral	30	68
non-late seral	15	34
Klamath-Sierra transition		
late seral	20	20
non-late seral	10	10
Northern Sierra		
late seral	5	5
non-late seral	2.5	2.5
Central Sierra		
late seral	10	1.0
non-late seral	5.0	0.5
Southern Sierra		
late seral	30	30
non-late seral	15	15
Power		
untransformed	0.87	0.88
arcsine transformed	0.80	0.79

Table 4. Classification table based on 1996 survey results in the Klamath study area. For details, see Carroll (submitted).

	Classified		Total
	<u>Presence</u>	<u>Absence</u>	
Observed			
Presence	24	3	27
Absence	7	6	13
Total	31	9	40

Table 5. Mean predicted probability value of land under different ownership and management.

	<u>Predicted Probability</u>
Overall	0.148
All Forest Service land	0.147
Matrix	0.145
Late Seral Reserves (LSR)	0.176
Forest Service reserves (wilderness)	0.119
Non-Forest Service reserves (parks)	0.231
Private land	0.179

Table 6. Characteristics of locations where fishers, gray fox, ringtail, and spotted skunk were, and were not, detected , 1 June 1996 - 1 November 1996. Comparison includes all stations (n = 240 on Klamath, 210 on Central Sierra).

	<u>Fisher</u>		<u>Gray Fox</u>		<u>Ringtail</u>		<u>Spotted Skunk</u>	
	Yes	No	Yes	No	Yes	No	Yes	No
Elevation (m)	863	903	751 ^a	943	596 ^a	939	802 ^a	906
Canopy closure (%)	88.6 ^a	81.6	83.9	84.6	86.6 ^a	83.5	79.6	84.8
Basal area (ft ² /acre)	206.2 ^a	184.4	192.8	191.3	179.4	193.9	178.5	194.3
Percent conifer	63.1	60.4	47.4 ^a	66.8	46.0 ^a	64.0	53.2 ^a	62.9
Hardwood DBH (cm)	26.3 ^a	17.0	25.5 ^a	18.1	31.2 ^a	18.3	24.5 ^a	19.3
Conifer DBH (cm)	61.6	66.9	70.1	63.2	57.7	66.5	61.9	65.8
Log count	3.75 ^a	6.37	5.01	5.66	3.40	5.84	5.95	5.39
Snag count	1.0	1.1	1.0	1.1	0.7	1.1	1.0	1.1

^a Significant intraspecific comparison (locations with vs. locations without a detection of each species), P < 0.05; Wilcoxon rank test.

Klamath Study Area

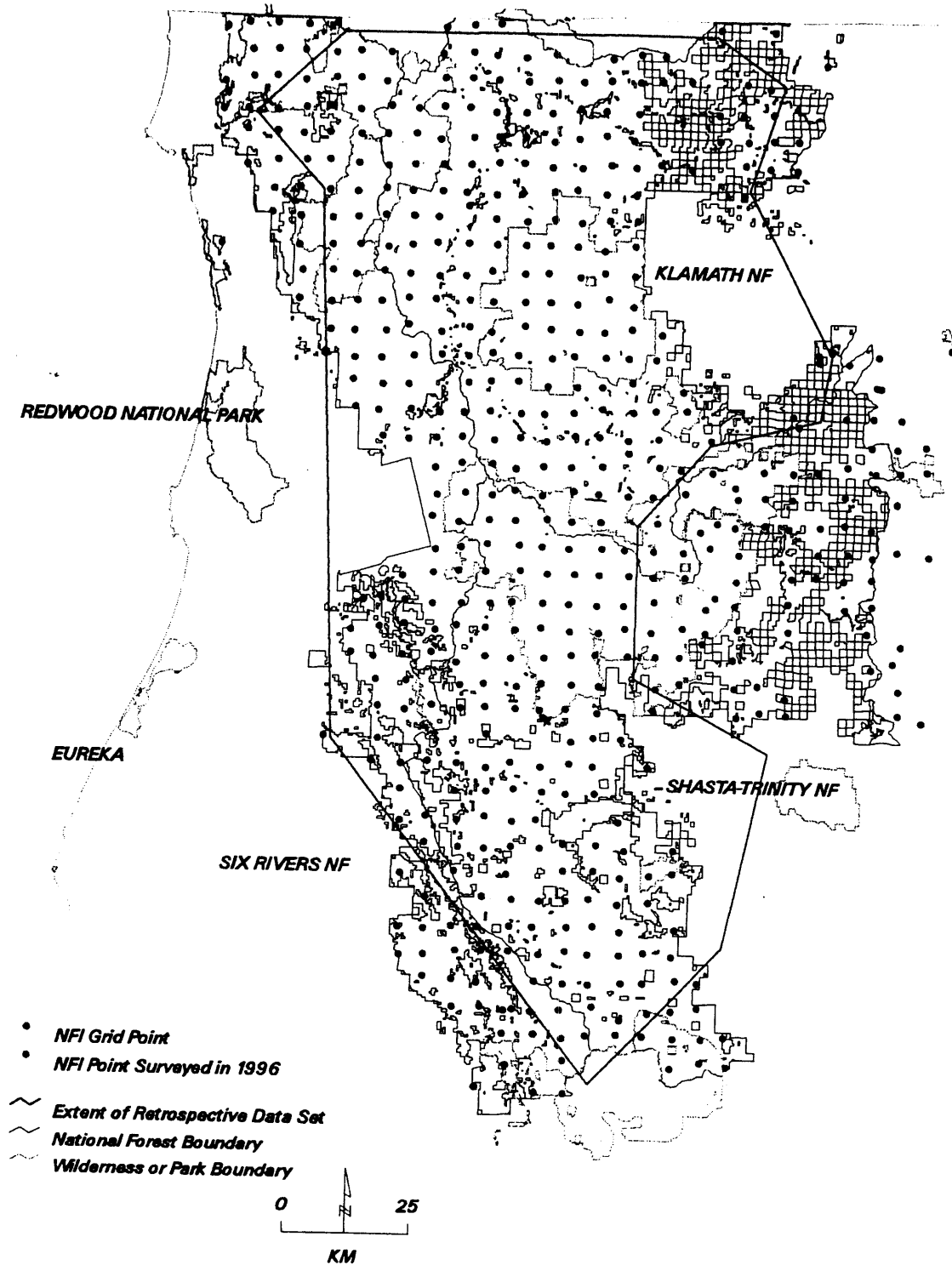


Fig. 1. Klamath study area, Six Rivers National Forest (NF), Klamath NF, Shasta-Trinity NF, and Redwood National Park.

Central Sierra Nevada Study Area

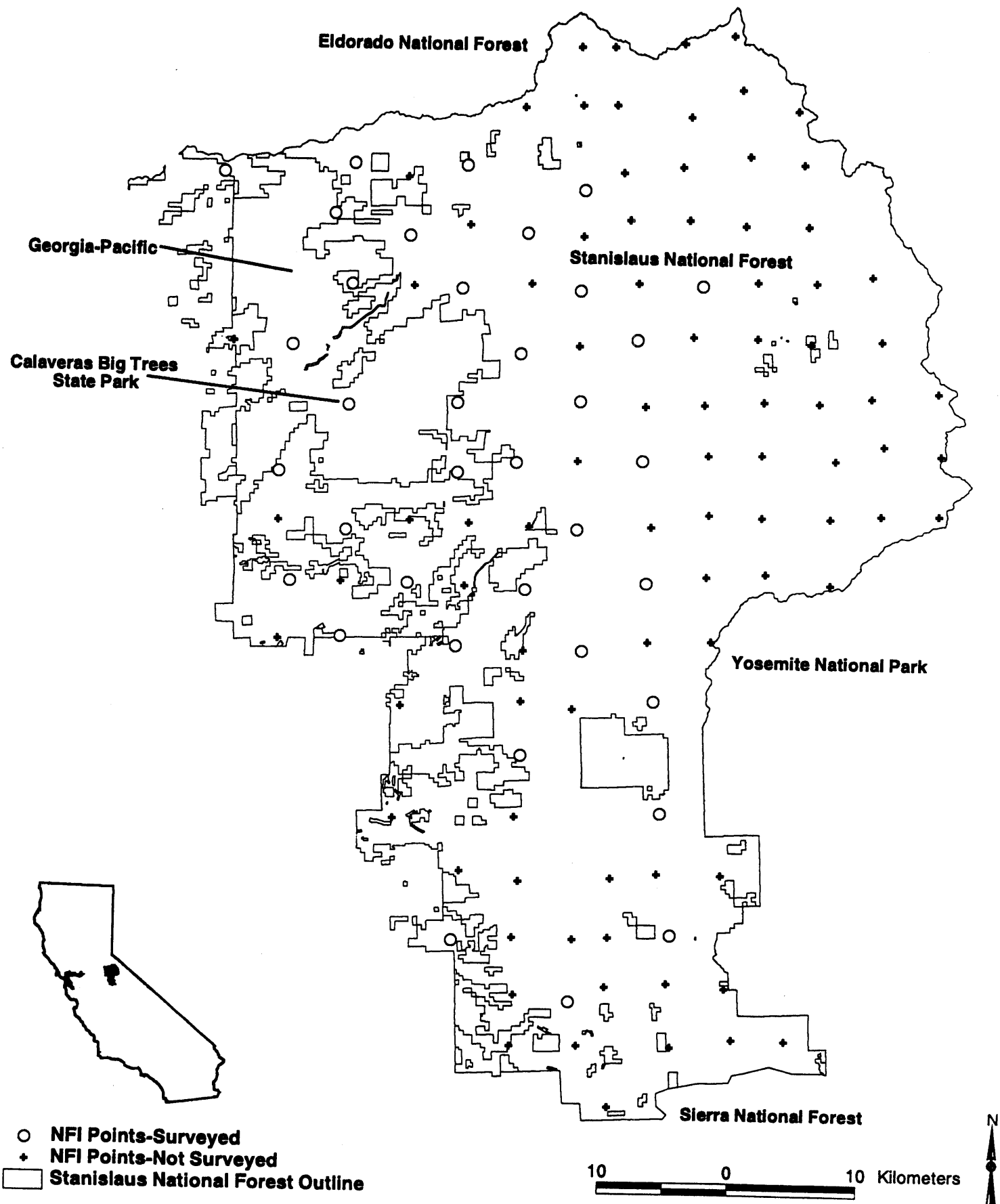


Figure 2. Central Sierra Nevada Study Area.
Stanislaus National Forest, Calaveras Big Trees State Park, Georgia-Pacific

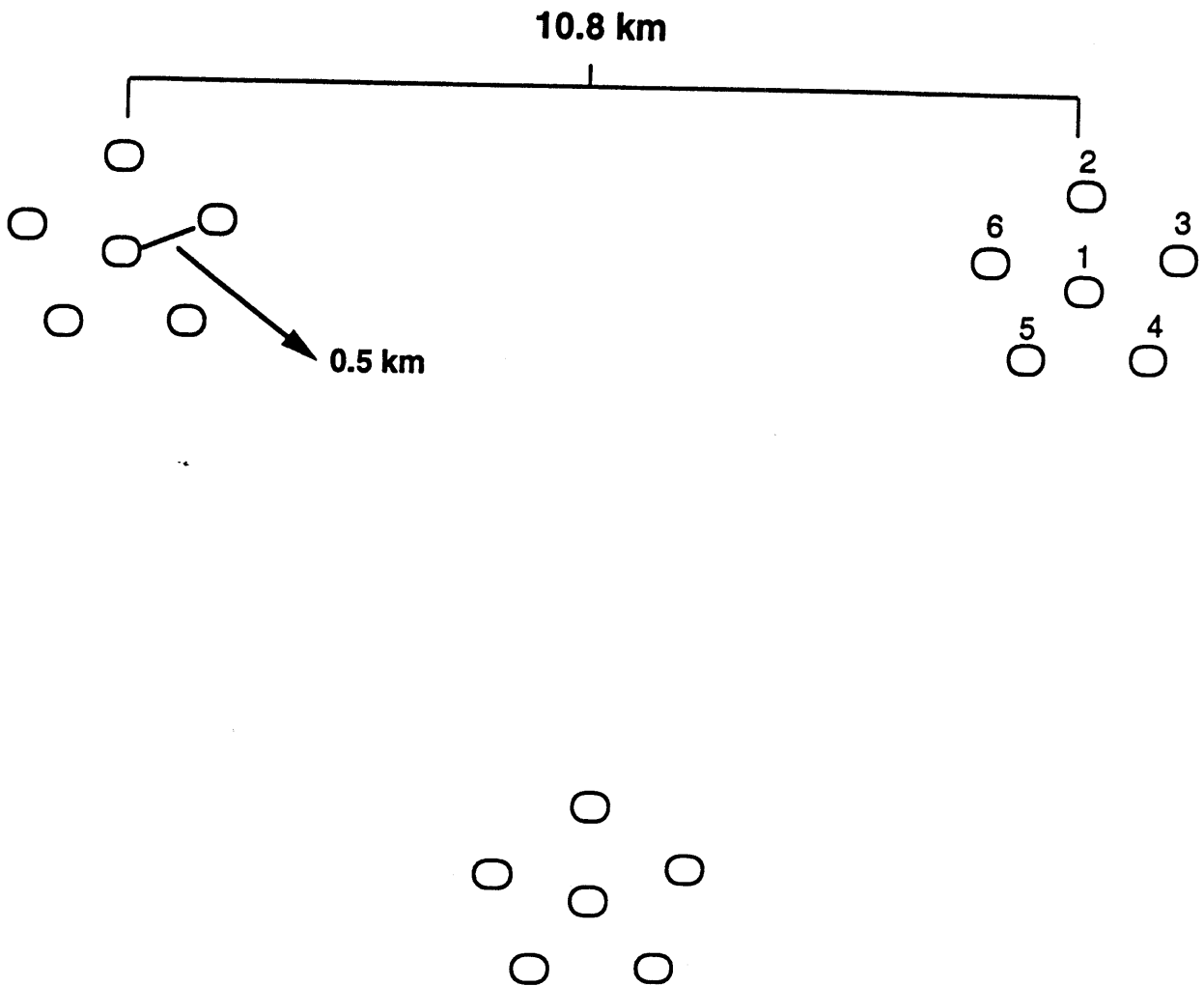


Figure 3. Distribution of sampling units. Station #1 (center) was aligned on the NFI grid point. Alternating aluminum and wooden enclosures were placed in a circle around it, separated by a distance of 0.5 km.

Fisher Detections Klamath Study Area

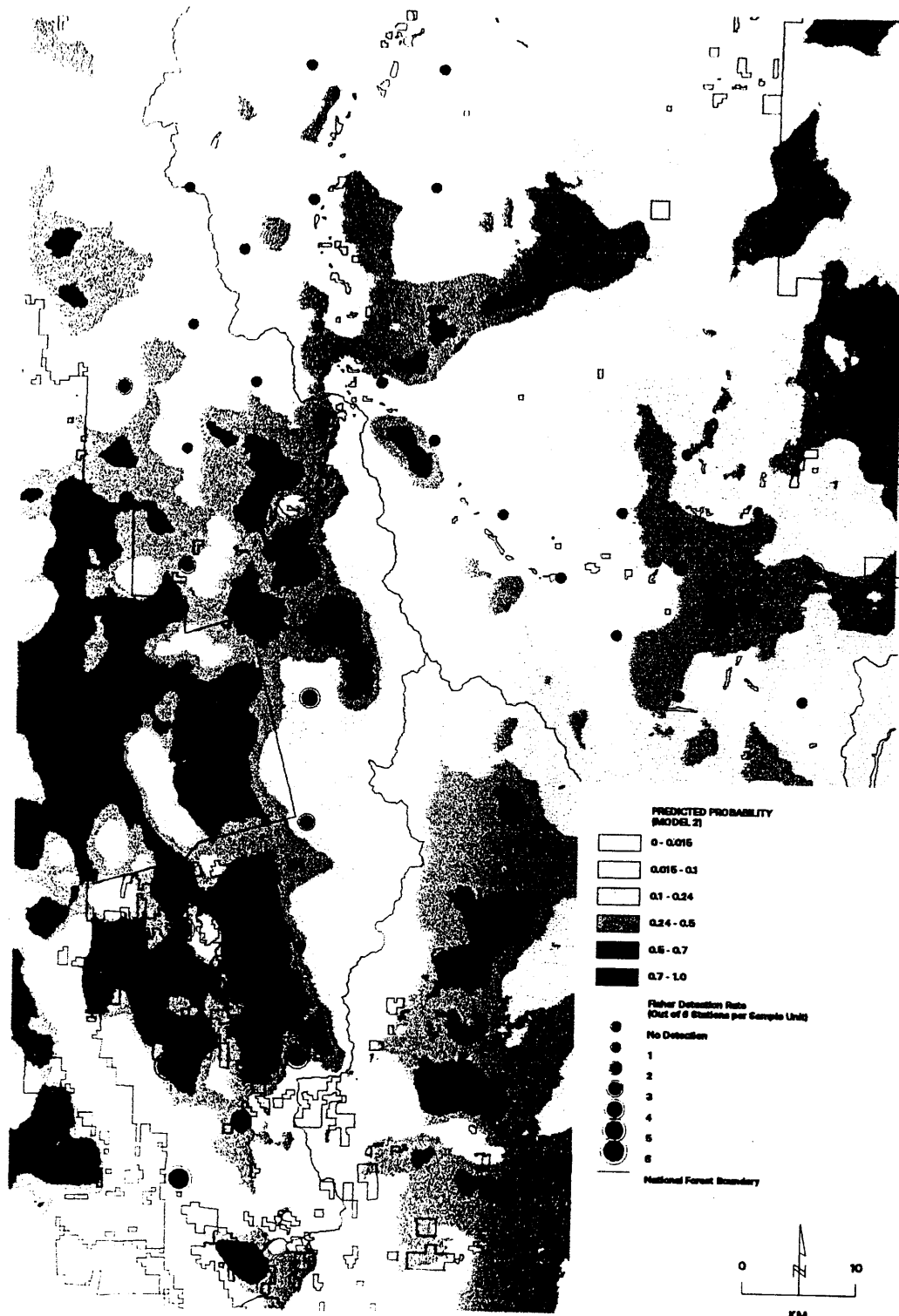


Fig. 4. Fisher detections at track plate stations on the Klamath study area, 1 June - 15 November 1996.

Gray Fox Detections Klamath Study Area

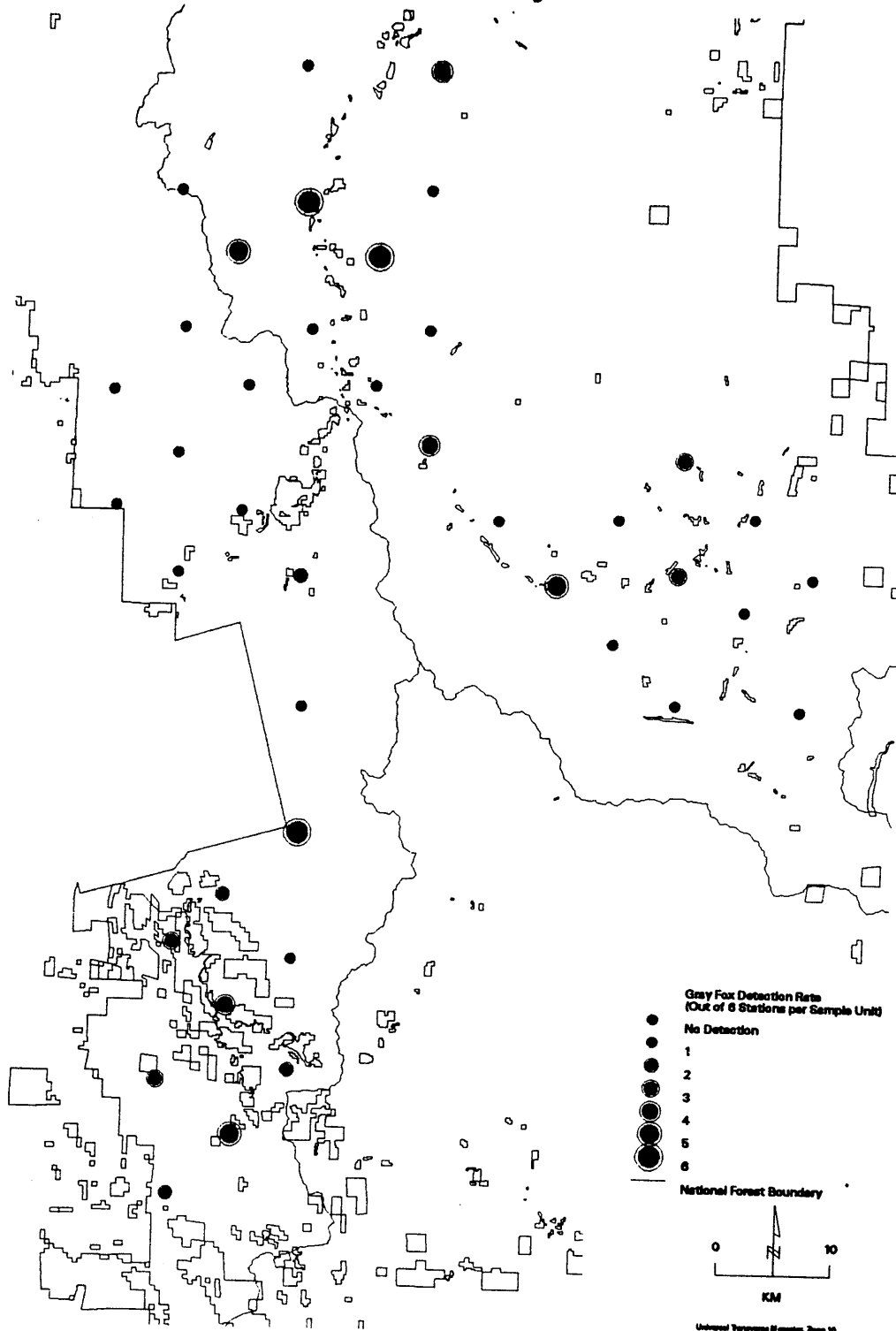


Fig. 5. Gray fox detections at track plate stations on the Klamath study area,
1 June - 15 November 1996.

Ringtail Detections Klamath Study Area

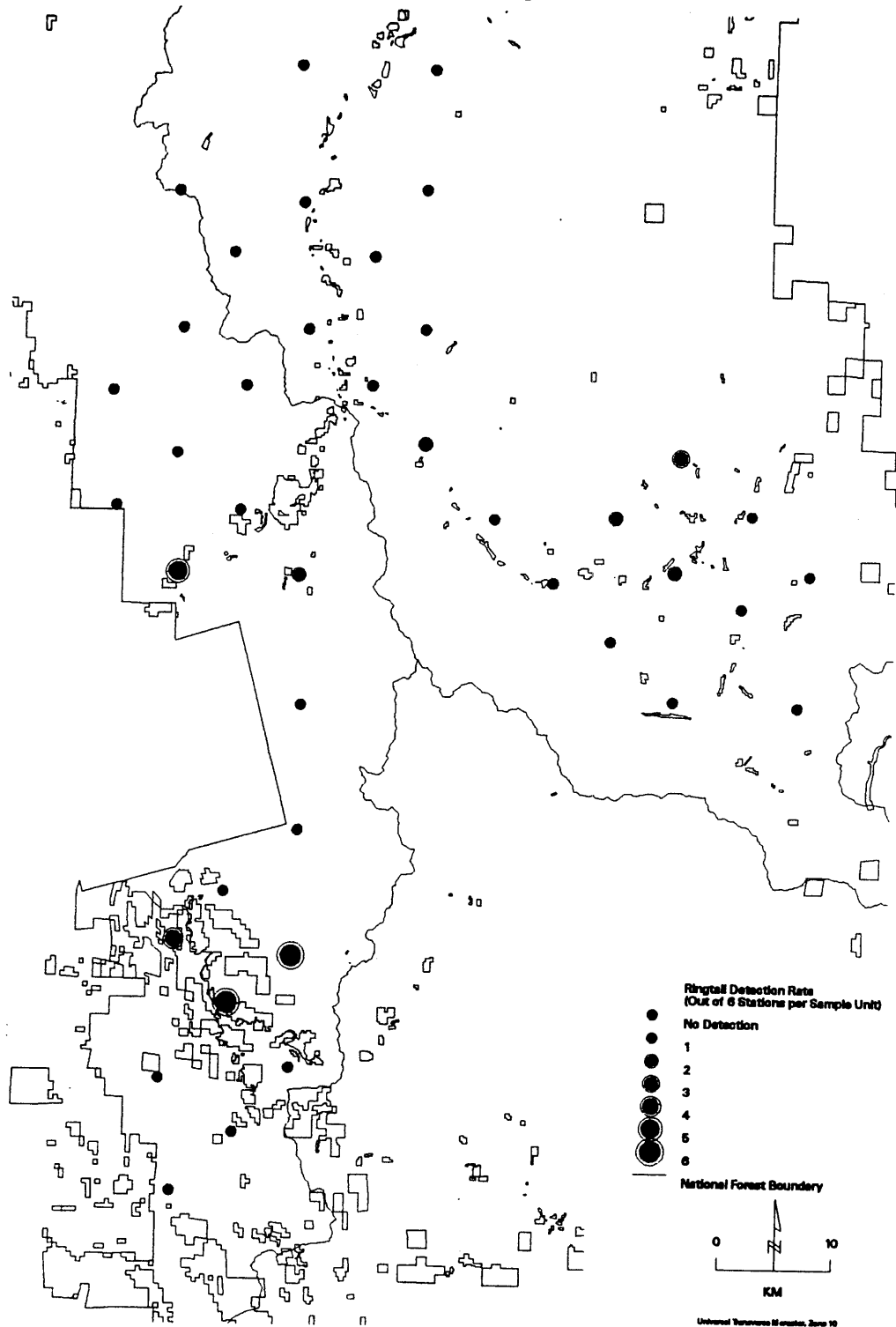


Fig. 6. Ringtail detections at track plate stations on the Klamath study area,
1 June - 15 November 1996.

Spotted Skunk Detections Klamath Study Area

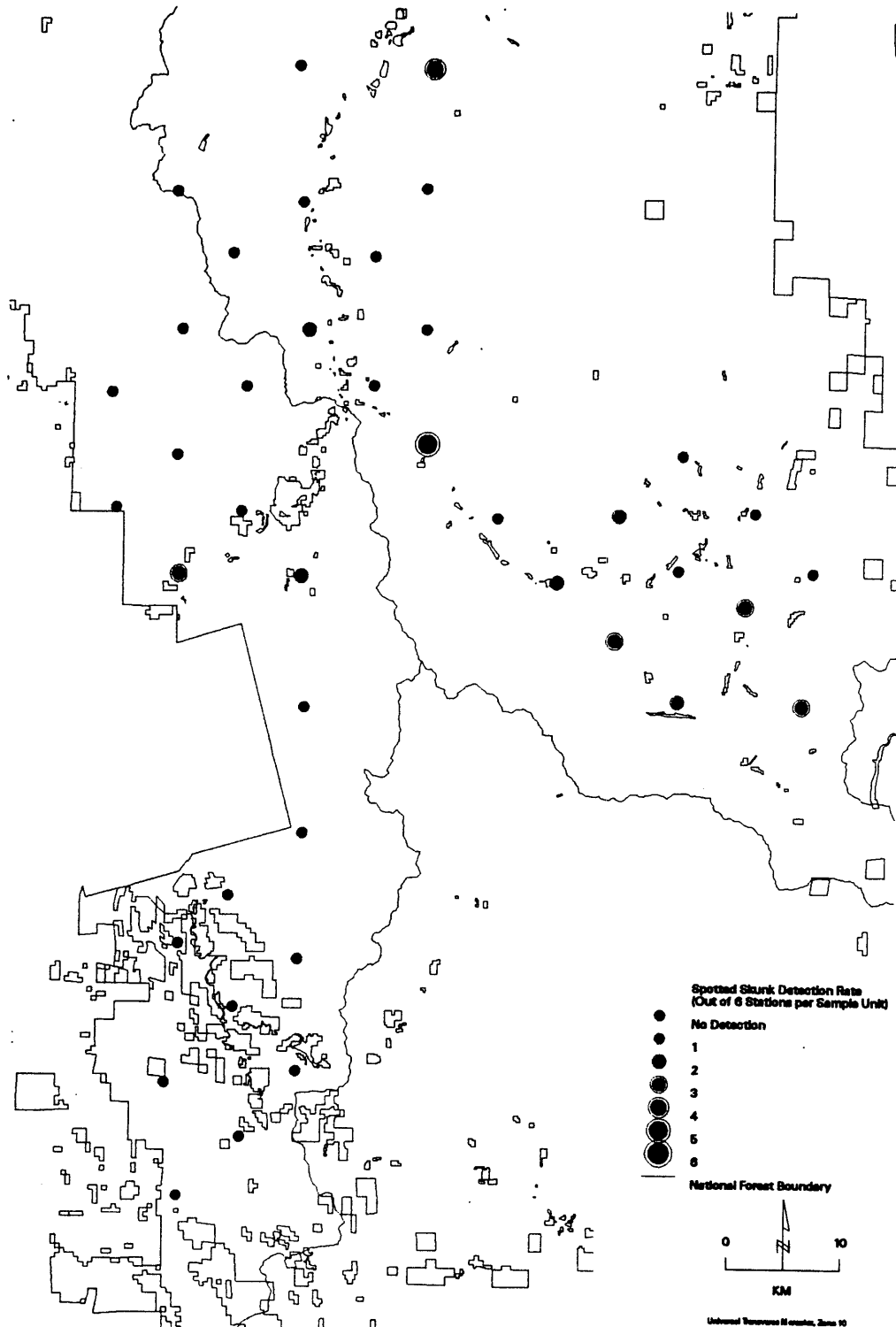


Fig. 7. Spotted skunk detections at track plate stations on the Klamath study area, 1 June - 15 November 1996.

Gray Fox Detections

Central Sierra Nevada Study Area

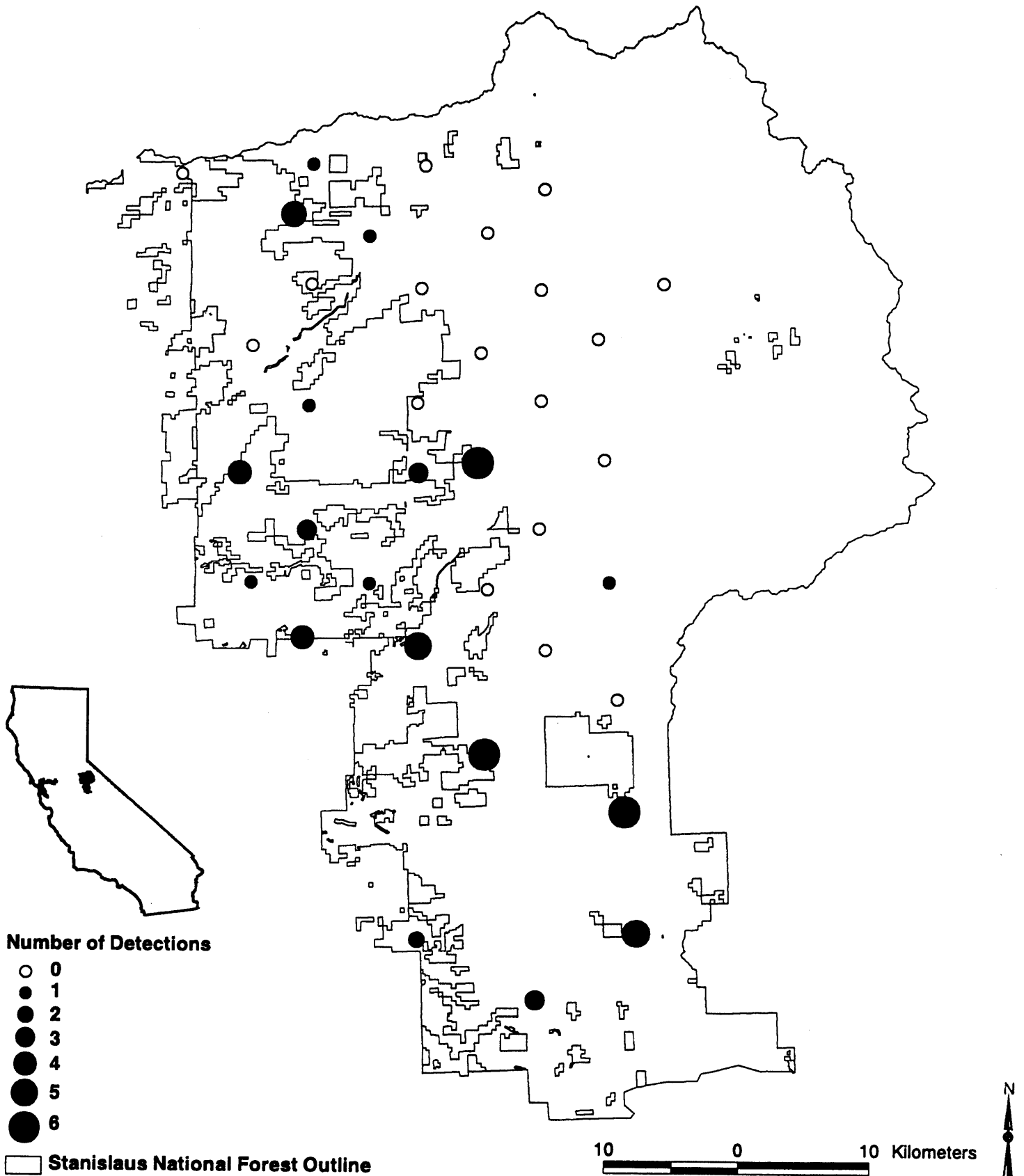


Figure 8. Gray Fox detections at track plate stations on the Central Sierra Nevada study area, 1 June - 15 Nov. 1996

Ringtail Detections

Central Sierra Nevada Study Area

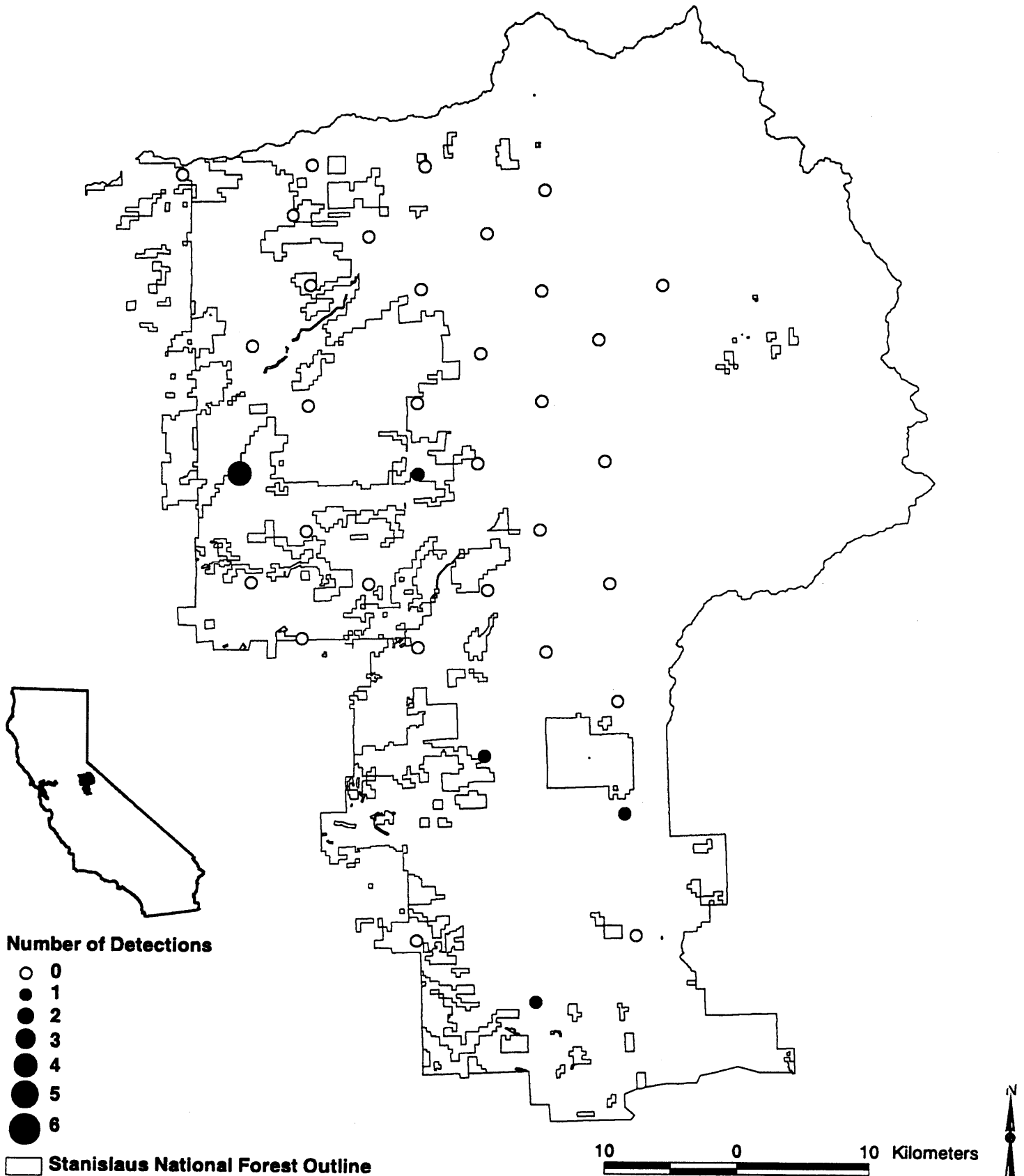


Figure 9. Ringtail detections at track plate stations on the Central Sierra Nevada study area. 1 June - 15 Nov. 1996

Spotted Skunk and Marten Detections

Central Sierra Nevada Study Area

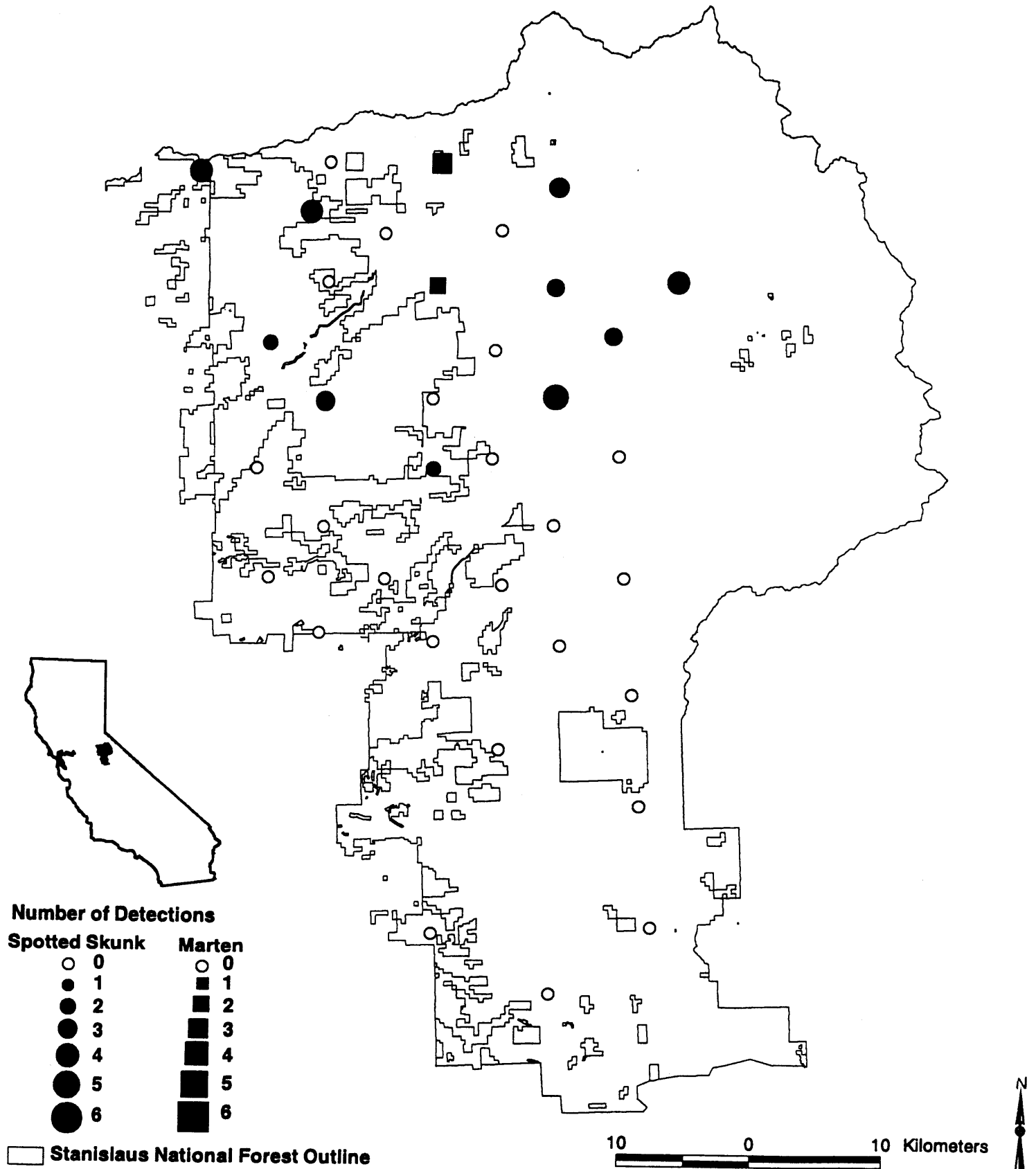


Figure 10. Spotted Skunk and Marten detections at track plate stations on the Central Sierra Nevada study area, 1 June - 15 Nov. 1996