SYSTEMATIC SURVEYS AS A BASIS FOR THE CONSERVATION OF CARNIVORES IN CALIFORNIA FORESTS - Progress Report II: 1996 - 1999

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William J. Zielinski*, Richard L. Truex*†, Lori A. Campbell*‡, Carlos R. Carroll‡‡, and Fredrick V. Schlexer*

*USDA Forest Service, Pacific Southwest Research Station,
Redwood Sciences Laboratory, Arcata, CA
†Department of Environmental Science, Management and Policy,
University of California, Berkeley, CA
‡Ecology Graduate Group, University of California, Davis, CA
‡‡Klamath Center for Conservation Research, Orleans, CA
bzielinski@fs.fed.us, rtruex@fs.fed.us, lcampbell@fs.fed.us, carlos@sisqtel.net
rschlexer@fs.fed.us

SUMMARY

From May 1996 – November 1999 we conducted systematic surveys for carnivores in forested landscapes of northwestern California, the Sierra Nevada, and Southern Cascades. Our main objectives were to (1) describe the geographic range of fishers, martens, and other mammalian carnivores in the region; (2) collect data to develop and test regional habitat models for fishers, martens, and other carnivores; (3) provide baseline data for monitoring changes in population status for these carnivores; and (4) understand the influence and interaction of habitat factors, community ecological factors, and anthropogenic effects on the distribution of carnivores in the region. Our survey protocol involves deploying sample units throughout national forest and national park lands occurring within the fisher's historic geographic range in California, using the 3.4 mile National Forest Inventory (NFI) grid as the template for locating sample units. Sample units were deployed at every other NFI point and included an array of 6 enclosed track plate stations covering ~1 km^2; each sample unit was deployed for 18 days and each station was checked for tracks every other day. Most sample units also included one or more remotely

triggered camera. During the 4-year reporting period, we deployed 299 sample units (composed of 2032 track plates and at least one camera at most of the sample units) across 8 National Forests and 2 National Parks. Key findings to date are as follows:

1. Thirteen carnivore species or species groups were detected at one or more sample units. The most frequently detected species were black bear (detected at 186 sample units) and spotted skunk (108 sample units). Other species detected included gray fox, fisher, ringtail, striped skunk, weasel spp., marten, unknown canid, unknown felid, raccoon, and badger.
2. Neither wolverine nor Sierra Nevada Red Fox were detected.
3. Fisher were detected in Northwestern California, the Mount Shasta area, and the southern Sierra Nevada (from Yosemite NP south).
4. Marten appear to be extremely rare in northwestern California. Detections at 2 sample units within the range of the Humboldt marten provided the first verifiable evidence of this subspecies in over 50 years.

A regional habitat model has been developed for the fisher in northwestern California, and habitat models for fisher and marten in the southern Sierra Nevada are expected to be completed in January 2001. Surveys are currently occurring on Lassen National Forest and will be conducted on Plumas and Tahoe National forests during 2001, as funding permits. We expect sampling to conclude during 2002 at which time analyses will begin to meet remaining research objectives.

INTRODUCTION

It has recently been acknowledged that management of public forestlands in California and elsewhere requires a bioregional perspective that addresses the effects of management outside individual national forests and park boundaries (Johnson et al. 1999). Ecosystem dynamics and animal and plant populations are affected by landscape and regional factors that do not align with administrative boundaries. Two large assessments that have included forest lands in California, the President's Northwest Forest Plan (USDA and USDI 1993) and the Sierra Nevada Draft Environmental Impact Statement (USDA 2000), are recent examples of this approach and are an expression of the increasing influence of conservation biology and ecosystem science on the management of public lands. With the adoption of a larger spatial and temporal view comes the need for information about wildlife habitat and abundance at larger scales.

Carnivorous vertebrates provide important information about the integrity of natural systems. Their presence in communities is linked to the integrity of ecosystem function because their dependence on abundant and diverse prey and their disproportionately large home ranges and low densities make them vulnerable to population declines (Minta et al. 1999). Furthermore, carnivorous vertebrates play a number of important functional roles in ecosystems including energy transfer, scavenging, fruit dispersal and the regulation of populations of prey species (Buskirk 1999). Lacking the influence of predators, prey can cause major changes to plant communities and entire ecosystems (Terborgh et al. 1999). We believe that an understanding of the distribution, habitat needs, and abundance of mammalian predators is central to the proper management of forest lands. Thus, in 1996, we embarked on an ambitious project designed to collect information on the distribution of carnivorous mammals in the national forests and parks in California. The first steps of the project were summarized in the initial progress report (Zielinski et al. 1997). The purpose of this report is to describe the progress of our work through November 1999 and to outline our plans for the conclusion of the study.

The project has 5 objectives:

1. To describe the geographic distribution of fishers (*Martes pennanti*), martens (*M. americana*), and other mammalian carnivores throughout the forested landscapes of northwestern California and the Sierra Nevada.
2. To collect data that are useful in developing and testing multi-scale habitat models for fishers, martens and other carnivores.
3. To collect data that are useful in monitoring change in the status of populations of fisher, martens and other carnivores.
4. To understand the influence and interaction of habitat factors and community ecological factors (e.g., the potential competitive influence of other carnivores) on the distribution of carnivore species in California.
5. To understand the influence of anthropogenic effects (e.g., vegetation management, urbanization, recreation) on the distribution of carnivore species in California.

The project began with the primary goal of estimating parameters for a simulation model that was created to estimate the statistical power of various sampling designs to detect statewide declines in indices of fisher or marten populations (Zielinski and Stauffer 1996). We also wished to use a more rigorous method to verify the purported absence of fishers within the central and northern Sierra Nevada revealed by a previous analysis of pre-project surveys (Zielinski et al. 1995). We soon realized that rigorously-collected data, using a probability-based sampling design, would have a wide variety of applications. In particular, these data could be invaluable in developing and testing multi-scale landscape habitat models for fishers and any other species that was frequently detected.

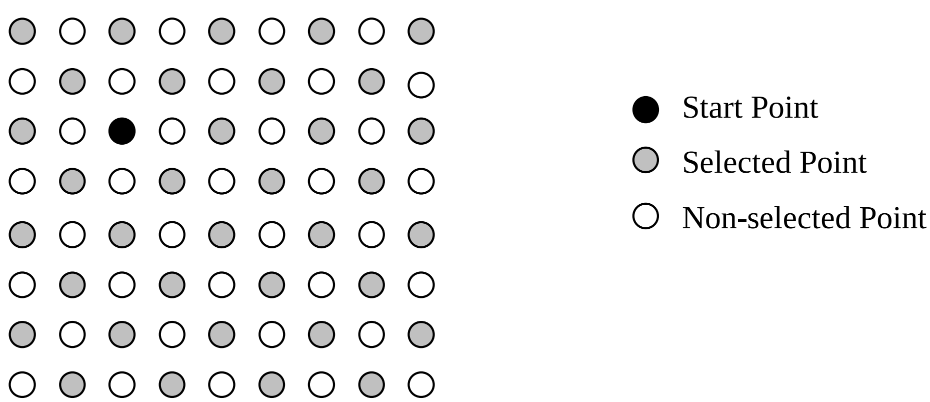
METHODS

Study Areas

The study has been conducted by identifying specific areas for inventory during particular years with the goal to cover the entire survey area in 6-7 years (Fig. 1). Most of the study areas were associated with the graduate project of an individual student and the data were collected by field crews composed largely of seasonal employees of the Forest Service. The Klamath study area (Fig. 1) included portions of the coast ranges of California and Oregon, was sampled from 1996-1998, and the data were used for the thesis of Carlos Carroll at Oregon State University (Carroll 1997). The Central Sierra study area (Fig. 1) was sampled from 1996-1999 and was the focus of the graduate work of Lori Campbell at UC- Davis (Campbell, in prep.) [Note that what we refer to as the Central Sierra study area includes areas as far south as the Sierra National Forest]. The Southern Sierra study area (Fig. 1) includes areas in and around the Sequoia National Forest and Sequoia-Kings Canyon National Park and was sampled as part of the graduate work of Rick Truex at UC-Berkeley (Truex, in prep.) from 1998-1999. The Southern Cascades survey began in 1999 and was not associated with a graduate student project.

Sampling Design

We deployed our sample units using a systematic survey design because this is the least biased approach when the goal is to uncover spatial structure in the data (Haining 1990) and because we could use the existing National Forest Inventory (NFI) 3.4 mile (~5 km) grid. The NFI grid is the basis for the USDA Pacific Southwest Region (Region 5) program of vegetation monitoring. Sample locations were included based on the random chance that they fell at the grid point. Thus, this was a 'probability-based' sampling design, unlike surveys that occur only along roads or which are stratified based on some perceived notion of suitable habitat, or are located only in areas where management activities are planned. All points in the grid that fell within or near the historical range of the fisher (Grinnell et al. 1937) were initially selected because this region includes much of the forests of the North Coast, Klamath, Cascades and Sierra Nevada mountains in California. The remaining NFI grid points were then assigned a row and column number, from which a random point was selected. From this start point, *every other* point in the row was selected to the eastern and western boundary of the grid. The same grid density (approximately 6.8 miles [10.9 km] between points on the E-W and N-S axes; 4.8 miles [7.7 km] on diagonal axes) was maintained for all subsequent rows, but each row was offset by 1 NFI point to create a grid with the same spatial properties as the original grid but with approximately half the number of points, as illustrated in the following schematic:

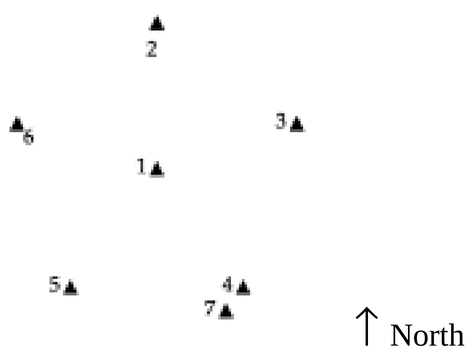


The distance between sample points was set by the need to fulfill the assumption of spatial independence for fishers, the species with the largest home range of those we expected to detect. We wanted to assure that no individual fisher would be detected at more than one sample unit. After subsetting the NFI grid as described we eliminated points that were below 800 m and above 3200 m in the southern Sierra Nevada, below 800 m and above 2700 m in the central Sierra Nevada and below 600 m and above 2900 m in the Southern Cascades. All elevations within the Klamath region were sampled. Certain points were eliminated if they were dangerous due to access, occurred exclusively on private land (except for a minority of sites in the central

Sierra Nevada and southern Cascades where we received permission to sample on private land), or were considered inaccessible (generally > 6 km from road access).

Detection Methods

At each selected grid point we established a sample unit composed of 6 sooted track plate stations (Zielinski 1995). A track plate station was placed as close as possible to the NFI point itself, and the remaining 5 track plates were positioned at 72° intervals approximately 500 m from the center point. Initially we began by enclosing the track plates in open-ended plywood boxes, however in 1998 we switched to plastic canopy-enclosed plates with a screen back (Zielinski 1995) after determining that detections did not differ at the wood and plastic stations when sample units were composed of 3 of each (Zielinski et al. 1997). All sample units, except those on the Klamath study area, also included at least one remotely-triggered 35-mm camera [two cameras were used on most Central Sierra sample units] (Kucera et al. 1995a) with the hope that this would increase the number of species detected. The camera was randomly paired with 1 (2 on the Central Sierra units) of the 6 track plate stations and placed ~100 m from the station at a random azimuth. In the following schematic, Station 1 is the NFI point (center point), Stations 2-6 are the remaining track plate stations and Station 7 is the camera station paired with track plate 4:



Sample units on the Central Sierra study area included also 2, 80 x 80 cm unenclosed sooted plates (Zielinski 1995), within 5 m of an enclosed plate. These were added with the hope that they might increase the detections of species like coyotes and bobcats that may be less likely to enter the enclosed track plate stations.

Map and compass were used to navigate as close to all the stations; our main objective was to establish each sample unit array so that it encompassed the NFI point rather than to attempt to locate the exact NFI point. We used a Global Positioning Satellite (GPS) receiver to record UTM coordinates at the majority of track plate and camera stations.

Field crews returned to all detection devices at 2-day intervals during the 16-day sampling duration, for a total of 8 visits. All stations were baited with raw chicken. In the Klamath and Southern Sierra regions, a commercial lure (Gusto) was applied to all sample units on the 5th visit if a fisher had not been detected at 1 or more track plate stations after half the survey duration (8 days; 4th check). In these regions we planned to use the fisher data to develop habitat models and delaying the use of lure meant that we could minimize the potential effects of drawing animals from unknown – but potentially long – distances until late in the sampling period when maximizing the number of sample units with fisher detections was a priority. Alternatively, we applied lure on the 1st and the 5th visit at each station in the Central Sierra and Southern Cascades regions because we wished to maximize our chance of discovering fishers in regions where they were presumed to be absent. Sampling was conducted from June 1 to November 1 each year.

Microhabitat (plot) Sampling

A combination of variable-radius plot and transect methods was used to describe the vegetation composition and structure at each station in each sample unit. Topographic variables included slope, slope aspect, topographic position and presence of water within 100 m. Basal area, tree diversity, condition class, abundance and size were estimated using prism sampling. Two, 25-m line intercept transects were used to tally the number of logs, and shrub cover was visually estimated. Canopy closure was measured using a spherical densiometer and facing each cardinal direction at the track plate station and at the ends of each transect. Each site was classified according to the California Wildlife Habitat Relationships (CWHR) system to assign a habitat type, size class and canopy cover to the area surrounding the track plate using guidelines provided by Mayer and Laudenslayer (1988).

Landscape Information in GIS

Because one of the primary uses of the data was to develop or test predictive landscape habitat models, point coverages for all sample units were created in GIS (ARC/INFO version 7.2.1). Differentially corrected GPS coordinates were used to build coverages whenever possible. Various environmental attributes, including remotely-sensed spectral images, classified vegetation and structural types, elevation and precipitation variables were intersected with sample unit coverages.

Various spatial modeling approaches were used (Carroll et al. 1999a), or are in the process of being used (Truex, in prep.; Campbell in prep.), to develop prediction surfaces over most study areas that rank the probability of occurrence of one or more species on the basis of correlated environmental and spatial variables. These models consider variables that range in scale from the microhabitat (plot), to landscape vegetation features, to regional trend surface phenomena (Bailey and Gatrell 1995) that are often explained by climatic variables.

Simple summaries of the habitat types that were sampled and those in which each species was detected were generated by intersecting the statewide CALVEG (Matyas and Parker 1980) coverage with the sample unit centers and summarizing the habitats in terms of their CWHR class equivalents. For the purpose of these simple comparisons 6 ‘habitat types’ were created from 14 CWHR types. The ‘shrub’ type included bitterbrush, mixed chaparral, montane chaparral and chamise-redshank. ‘Pine’ included ponderosa pine, eastside pine, Jeffrey pine and lodgepole pine. ‘Mixed conifer’ included Klamath mixed conifer and Sierran mixed conifer. ‘True fir’ included red fir and white fir, ‘Douglas-fir was not aggregated, and ‘Hardwoods’ included montane hardwood and blue oak woodland.

Monitoring Population Status

The proportion of sample units with a detection of a particular species is an index of the species’ population status in California. The groundwork for estimating the number of sample units necessary to detect change in this index was established in 1995 using Monte Carlo simulations and estimating statistical power (Zielinski and Stauffer 1996). Although the impetus for this work was to anticipate the sampling effort necessary to detect decreases in the index of marten or fisher detections, the work is generic and can be applied to the detections of any of the regularly occurring species. Summing the number of sample units that have been sampled with those we intend to sample provides an estimate of the sample size we will likely achieve for this project. This information, in combination with estimates of the proportion of sample units that have detected a particular species, will allow us to estimate the statistical power necessary to detect hypothetical declines in the index of each species' population. We conduct this analysis for the fisher and the spotted skunk, to contrast the effort required to monitor change in a rare and a common species. To explore the implications of detecting various types and magnitudes of change, we test the ability of our proposed sampling scheme to detect decreases and 'changes' (increase *or* decrease) of 20, 30 and 50%. The Type I error rate ($\propto$, the probability of detecting a decline or change when it did not occur) was fixed at 20%.

RESULTS

Survey Effort

During 4 field seasons, between May 1996 – November 1999, data were collected at 299 sample units (Table 1), which included 2,032 track plate and 343 camera stations. All of the sample units on the Southern Cascades, Central Sierra and Southern Sierra study areas (*n* = 221; 74%) included at least one camera. Only the sample units on the Klamath study area (*n* = 78) lacked cameras. The Central Sierra area received the greatest survey effort, and among the national forests and parks, the greatest number of sample units were deployed on the Shasta-Trinity, Sequoia and Stanislaus National Forests (Table 1).

Carnivore Detections

Carnivores (including for the purposes of this summary, the opposum [*Didephis virginianus*]) were detected a total of 3,970 times at track plates (Table 2). Black bear detections -- which were reported via either track, camera or when a station was seriously disturbed -- were the most frequently detected species (62.2 % of sample units). In decreasing order, western spotted skunk (*Spilogale gracilis*), gray fox (*Urocyon cinereoargenteus*), fisher (*Martes pennanti*), ringtail (*Bassariscus astutus*), striped skunk (*Mephitis mephitis*) and 'weasels' (*Mustela* spp.) were the next most frequently detected species, all occurring at between 12 - 37 % of the sample units (Table 2). The least frequently detected species (between 1 - 11 % of sample units) were the

American marten (*Martes americana*), opposum, ‘unknown cat’ (*Felis* spp. including bobcat [*Felis rufus*] and domestic cat [*Felis cattus*]), ‘unknown dog’ (*Canis* spp. including coyote [*Canis latrans*] and domestic dog [*Canis domesticus*]), raccoon (*Procyon lotor*) and badger (*Taxidea taxus*). There were no detections of either wolverine (*Gulo gulo*) or red fox (*Vulpes vulpes*).

Spotted skunks and black bears were the most ubiquitous species occurring on all study areas (Fig. 2), all national forests sampled (Table 2, 3; Fig. 3, 4) and across all elevations. Weasels (Fig. 5) also were detected throughout the region (Table 3), but far less frequently than spotted skunks and bears. Martens occurred at the highest elevations and striped skunks and ringtails at the lowest elevations (Fig. 6, 7, 8). Gray foxes were common throughout the regions surveyed but were less frequently detected in the southern Sierra Nevada than the fisher (Fig. 9, 10) and less frequently detected in the northwestern Klamath region than the spotted skunk (Fig. 4).

In the 221 sample units that included both track plates and cameras, carnivores were detected at the camera -- but not at any of the 6 track plate stations in the same sample unit -- at 22 of the (10.05%) of the sample units. The majority of these instances involved black bears (14 of 22 sample units; 64%). Fishers, spotted skunks, gray foxes and weasels were detected by camera only at 2, 3, 2 and 1 sample unit, respectively.

<u>CWHR Habitat Types</u>

The Pine and the Mixed Conifer types were the most frequently sampled habitat types across all study areas, followed by True Fir and Douglas-Fir (Fig. 1). Four species were detected most often, and almost equally within the Pine and Mixed Conifer types: striped skunks, spotted skunks, gray foxes and black bears (Fig. 3, 4, 7, 9). Ringtails, fishers, and weasels were each detected most often in the ‘Pine’ type and next most frequently in the Mixed Conifer and the Douglas Fir types (Fig. 5, 8, 10). The marten was the only species detected more frequently in the True Fir type than any other (Fig. 6). The ringtail, gray fox and striped skunk were the 3 species that had the highest frequency of occurrence in the Hardwood habitat type (Fig. 7, 8, 9). The habitats where black bears were detected most closely resembled the habitats at all sample units (Fig. 3 compared to Fig. 1), indicating that bears are habitat generalists.

Detections of Wolverines, Fishers and Martens

We did not detect a wolverine at any track plate or camera station. Fishers were most common in the Klamath and Southern Sierra study areas (37.2% and 44.0% of sample units, respectively; Table 2, Fig. 10). On average, fishers were detected 6.19 times at each sample unit. Fishers returned to the sample units at which they were originally detected more frequently on the Klamath study area (215 times) than on the Southern Sierra area (129 times), despite the similar percent of sample units with detections. Fishers were detected at less than 11% of the sample units on the Southern Cascades and the Central Sierra areas. The few detections in the 'Southern Cascades' study area actually occurred in the extreme western portion, nearest the Klamath area (Fig. 10). The detections in the Central Sierra area occurred at the southern end (the Sierra National Forest) and were much less frequent than in the adjoining Southern Sierra area. When fishers were detected in the Southern Cascades and Central Sierra areas, they were detected at fewer stations/sample unit (as indicated by the size of the red symbol; Fig. 10) than when they were detected in the central regions of the Klamath and Southern Sierra areas.

Martens were detected most frequently on the Southern Sierra study area (Fig. 2, 6) but they were never detected at more than 20% of the sample units on any of the 4 areas, probably because we seldom sampled elevations that were dominated by true fir (*Abies* spp.) habitat. Detections occurred throughout the Southern and Central Sierra Nevada (Fig. 2, 6), but the number of stations/sample unit at which martens were detected appears to be higher in the southern portion of the range (compare size of red symbols in Fig. 6). Martens were detected an average of 8.5 times at each of the sample units at which they occurred, compared to 6.2 times for fishers. Martens were detected commonly around Mt. Shasta in the Southern Cascades and were detected surprisingly often in the portion of the Klamath study area that occurred in southwestern Oregon (Fig. 6). Of greatest interest for martens was the discovery of a population within the historical range of *M. a. humboldtensis*, the Humboldt marten, for which there had been no evidence of occurrence during the previous 50 years (Zielinski and Golightly 1996; Zielinski et al. in press).

Status of the Development of Regional Habitat Models

Klamath Study Area

Using the data from previous, project-level surveys conducted by Forest Service staff and other surveyors (retrospective surveys) and the surveys conducted as part of this research project (prospective surveys) we have built, tested and published a spatial habitat model for the fisher in the Klamath study area (Carroll 1997, Carroll et al. 1999a). The abstract from the paper that appeared in *Conservation Biology* follows:

> "Forest carnivores such as the fisher have frequently been the target of conservation concern because of their association in some regions with older forests and sensitivity to landscape-level habitat alteration. Although the fisher has been extirpated from most of its former range in the western United States, it is still found in northwestern California. Fisher distribution, however, is still poorly known in most of this region where surveys have not been conducted. To predict fisher distribution across the region, we created a multiple logistic regression model using data from 682 previously surveyed locations and a vegetation layer created from satellite imagery. A moving-window function in a GIS was used to derive landscape-level indices of canopy closure, tree size class, and percent conifer. The model was validated with new data from 468 survey locations. The correct classification rate of 78.6% with the new data was similar to that achieved with the original data set (80.4%). Whereas several fine-scale habitat attributes were significantly correlated with fisher presence, the multivariate model containing only landscape and regional-scale variables performed as well as one incorporating fine-scale data, suggesting that habitat selection by fishers may be dominated by factors operating at the home-range scale and above. Fisher distribution was strongly associated with landscapes with high levels of tree canopy closure. Regional gradients such as annual precipitation were also significant. At the plot level, the diameter of hardwoods was greater at sites with fisher detections. A comparison of regional fisher distribution with land-management categories suggests that increased emphasis on the protection of biologically productive, low- to mid-elevation forests is important to ensuring the long-term viability of fisher populations."

Southern Sierra Nevada Study Area

Regional models of habitat suitability are being developed for fishers and martens in the southern Sierra Nevada from Yosemite National Park to Kern County (Truex, in prep.). The main objectives of these models are to predict the occurrence of fishers and martens throughout the region and to integrate the regional models for each species into a map of landscape suitability for *Martes*. Ultimately, these models can serve as a basis for developing regional conservation strategies for both species. Two analytical approaches, logistic regression and artificial neural networks, are being used to predict occurrence of each species across the region. Each method uses presence / absence survey data collected from 1989-1996 using track plates and remote cameras (‘retrospective’ data) as the response variable and a variety of environmental and abiotic variables as predictor variables. Environmental variables included in the modeling are all derived from Landsat TM data acquired during August of 1995. Raw Landsat pixel data are being used to derive several vegetation indices assumed to be important predictors of the regional distribution of fishers and martens. Included among these indices are the Tasseled Cap transformations of brightness, greenness and wetness (Crist and Cicone 1984) and Normalized Difference Vegetation Index (NDVI) modified for mid-IR reflectance (Nemani et al. 1993). Several factors influenced the decision to use Landsat-derived vegetation indices:

1. Landsat TM imagey is available for the entire region and thus permits the development of models across all ownerships using comparable predictor variables.
2. After geometric, topographic and radiometric correction of Landsat TM data, raw image data and derived vegetation indices are essentially free from error.
3. Although these vegetation indices do not correspond directly to habitat types commonly used to describe wildlife habitat relationships, they vary across the area with respect to dominant life form (e.g., shrublands, coniferous forest, exposed rock) and other regional features likely to influence regional distribution of wide ranging carnivores.
4. Updated regional maps of habitat suitability can be produced as needed using data collected under similar atmospheric and phenological conditions.

Although daily decisions made by fishers and martens are likely influenced by within home range habitat conditions, regional distribution is likely influenced by processes occurring at or above the home range scale. Accordingly, moving window functions (mean and standard deviation) will be applied in GIS to pixel-based vegetation indices to better represent processes influencing fisher and marten distribution. Five moving window sizes have been chosen to encompass home range sizes observed for the southern Sierra Nevada and range from 1 km^2 (female marten home range) to 50 km^2 (large male fisher home range). Model predictions will be tested using the systematic data described herein. Completion of this project is expected in January 2001.

Central Sierra Nevada Study Area

Because fishers do not occur through much of the Central and Northern Sierra Nevada (Zielinski et al. 1995) a habitat model cannot be developed for this species. Instead the focus of the graduate research project in this region is to consider the carnivore assemblage with which fishers once occurred. Given the fisher's apparent association with late seral, closed canopy forests and the reduction in these habitats over time (Sierra Nevada Ecosystem Project 1996), habitat alteration is likely a contributing factor to the observed contraction of the geographic range of fishers in the Sierra Nevada. When previously closed canopy stands are opened or fragmented, generalist species such as bobcats and gray foxes can move in and may be better adapted to the modified habitat than a habitat specialist such as the fisher. These species may affect the ability of fishers to persist in or recolonize mature stands, compounding the effects of habitat change. The objectives of this research are: to identify the patterns of association among carnivorous mammals, to understand the habitat associations of species that occur with fishers elsewhere, and to determine how the presence of these other species may affect the restoration of fishers to this region. Detection locations and attributes such as vegetation, topography, road density, and management status are being related in a GIS to describe the observed patterns of species occurrence. Habitat models are being developed using multiple logistic regression techniques, incorporating variables from plot, landscape, and regional scales for frequently detected species such as spotted skunks, gray foxes, ringtails, and black bears that are known to occur with fishers elsewhere. Results from the analyses of species associations and habitat associations will be used to evaluate the possible effects of other species on the potential for restoration of fishers in the central Sierra Nevada region. Completion of this project is expected in June 2001.

Monitoring

The results of the sampling conducted to date provide reasonable estimates of the proportion of sample units that received detections (Fig. 11) in each of the 5 strata that were originally proposed (Zielinski and Stauffer 1996). This information, together with the likely sample size in each stratum, is all that is necessary to estimate the statistical power to detect declines or increases in our index of abundance. We expect that with sufficient funding we will conclude our California surveys in 2001 or 2002. At this time we estimate we will have surveyed a total of 550 sample units or approximately 110 within each of 5 strata. Estimates of statistical power differ considerably when the data for a rare species, the fisher, is compared with a ubiquitous species like the spotted skunk. A 20% decline in the index of fisher abundance can be detected 77% of the time whereas a similar decline in the index of spotted skunk abundance can be detected 87% of the time (Table 4). Detecting an increase or decrease (an absolute change) is more difficult to detect for both species, generating only 50% confidence for the fisher. Greater magnitudes of change (50% vs. 20%) are detected with greater confidence (Table 4).

DISCUSSION

We view large-scale regional surveys as an essential step toward understanding the distribution, abundance and habitat of mammalian predators. This information is critical for the conservation of carnivores in forests. Carnivores have important roles in ecosystems (Buskirk 1999) and are potential indicators of the effects of human alterations on forestlands (Noss et al. 1996). We believe that large-scale surveys to detect presence can complement, and in some cases substitute for, the information that is acquired via traditional telemetry studies. Spatially intensive, telemetry-based, studies are useful for describing habitat elements that are used within home ranges and in estimating survival and reproduction for individual species. However, they are usually limited to a relatively small area of a species' range and typically occur where the species of interest is common, limiting the area over which conclusions apply. Furthermore, these studies usually focus on a single species, ignoring the community of co-occurring species of carnivores and their potential effects on the target species. Spatially-intensive telemetry-based studies also require special skills and usually demand a year-round field presence that increases their cost.

The data presented here are of more value for regional than local planning. The survey sites in our 10-km grid are not always in the locations where project-level information is required to evaluate the effects of individual management activities (e.g., timber harvest). However, sample sites are never more than 5 km away from an affected area and the habitat models developed from survey data can be used to evaluate the effects of a management activity on potential habitat in nearby areas that have not been surveyed. The coarse scale of sampling we use provides data at a scale that is relevant to the threats that face ecosystems today. For example, without information about the current distribution of fishers and martens the Sierra Nevada EIS and Framework would be uninformed of the effects of management on potentially isolated carnivore populations (e.g. fishers in the southern Sierra Nevada), would not be aware of the elevational range above which forest management will affect the habitat of martens, and would have little knowledge of the specific regions where forest carnivore populations are expanding into previously occupied habitat.

The essential value of multi-scale habitat models for large, multiple-ownership regions should not be overlooked. Although examples of these models have only recently been made available (e.g., Mladenoff et al. 1995, Carroll et al. 1999a, Mace et al. 1999) they define effects at a scale that could not be imagined before the routine access of remotely-sensed satellite information about vegetation, topography and climate. Information at this scale is the dominant source of knowledge for long-term and large-scale conservation planning (Soulé and Terborgh 1999). Output from these models can be used to compare the habitat suitability of lands with different management history and emphasis or lands managed by different agencies (e.g., Carroll et al. 1999a). In addition, habitat models developed for separate species can be compared to understand the habitat attributes that are of mutual value and the attributes that separate the needs of one species from another (e.g., Lindenmayer et al. 1994, Carroll et al. 1999b, Carroll et al. in press).

These types of surveys also establish a baseline of understanding about the distribution and habitat of many species that may not be threatened by human activities today, but may be in the future. Periodic sampling of the distribution of these species will help us detect changes in populations that warrant conservation actions. Historically, this information was provided by trapping records, but many of these species are no longer harvested for their fur in California. Even for those that are, the records of the location of harvest are usually only available at the county level. Thus, the regional systematic, grid-based survey protocol described here is the best method for gathering the spatially extensive data that is essential to evaluate the effects of forest management on forest carnivores.

The surveys that have been completed to date reinforce some of the same conclusions that were drawn from the analysis of pre-existing (retrospective) survey data summarized for fishers and martens in the mid-1990s (Zielinski et al. 1995, Kucera et al. 1995b). Although there is still a large area where surveys are incomplete, the new data reported here do not alter the previous conclusion that fishers are either absent from, or at extremely low densities, in the region between Yosemite National Park and the Mt. Shasta area. These new surveys have documented, however, that fishers occur east of Interstate 5 in Shasta County (Fig. 10). A shortcoming of the current survey protocol is that it is centered on an elevational range below the center of the distribution of martens in the Sierra Nevada. Despite this, martens were detected throughout most of the Sierra Nevada, though less frequently than we expected in some of the highest elevations that were surveyed in the Central Sierra Nevada study area. Additional surveys will need to be completed above 2500 m elevation if we are to adequately describe the distribution of martens and monitor their populations in the Sierra Nevada. In northwestern California the current surveys were successful in detecting -- for the first time in 50 years -- martens within the historical range of the Humboldt subspecies (*M. a. humboldtensis*) (Zielinski et al. in press). Prior to 1996 no surveys in this region had detected martens, but very few surveys had been conducted independent of roads until now. Furthermore, one of our 2 detections of a marten in the Klamath region occurred in habitat that was so unorthodox (open canopy, brush) that local biologists would not have been inclined to search there. The probability-based, systematic surveys described here avoid biases associated with road access and with assumptions about what constitutes appropriate habitat.

Our surveys are not easy to execute. Gaining access to, and conducting surveys in, the types of locations called for in a systematic approach requires personnel with field skills that exceed those of crews that conduct traditional, road-based surveys. However, the installation and operation of the detection devices is easy, is described in a published protocol (Zielinski and Kucera 1995), and requires very little training to accomplish. Moreover, the sample sites are also those used by the US Forest Service's Forest Inventory and Analysis (FIA) program so that there is often pre-existing information available about how to locate the site. And, there are data on forest structure and composition collected at each of these points on a periodic basis by the FIA program that may be useful in the future for developing habitat models, especially for species with small home ranges for which these fine-scale data may be relevant.

A potential shortcoming of the sampling design chosen is that it was initially developed with fishers in mind. Thus, the sample units are relatively far apart to assure some level of spatial independence for the purpose of monitoring the fisher population. This arrangement will sample a smaller proportion of the population of species with smaller home ranges. Some of our preliminary data suggest that this may have an impact on interpreting indices such as the number of detections per sample unit. Gray foxes and spotted skunks had the highest average numbers of detections per sample unit (9.29 and 8.07, respectively), which may have to do with the fact that they have relatively smaller home ranges (< 1 km^2 for spotted skunks, 1-8 km^2 for gray foxes; Chapman and Feldhamer 1982). When sample units fall within these smaller home ranges they may generate more detections per sample unit than for species with larger home ranges. This may be inconsequential, however, if we do not use this metric as an index of local abundance. How we interpret the data collected for each species will be a function of the inter-sample unit distances, home range size, the degree of intraspecific territoriality, and density. Each of these will need to be considered, and perhaps evaluated via simulation modeling, when we develop the next steps of our multiple species monitoring program.

Our regional, systematic surveys are relatively inexpensive, sample more than a dozen species simultaneously, and generate information that can be used to model habitat associations and to monitor population status. In addition, these systematic surveys are the ideal means to locate patchily distributed populations, even of species that have gone undetected for decades using other methods (e.g., the Humboldt marten; Zielinski et al. [in press]). Extensive regional surveys provide information at a scale that is commensurate with the scale at which many of the threats to the viability of carnivores occur. Human residential development, cumulative effects of timber and vegetation management, roads, and many other effects of humans on wildlife habitat occur over such large spatial scales. And, the home range sizes of many of the species of interest make it difficult or impossible to address issues of viability by considering the impacts of individual forest management projects. We suggest that periodic extensive surveys, such as the kind described here, are the best means for addressing the concerns about the conservation of carnivores in forests. They can describe current geographic range, be used to develop habitat models at scales that are relevant for decision-making, and provide information that can be used to monitor an index of population abundance.

Surveys are currently occurring on Lassen National Forest and Lassen Volcanic National Park and will be conducted on the Plumas and Tahoe National Forests during 2001, as funding permits. We expect sampling to conclude during 2002 at which time our analyses will begin to meet the remaining research objectives.

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Table 1. Number of sample units that occurred in each region of the state and each National Forest or National Park; 1996-1999.

Region		National Forest or Park	
Klamath	78	Siskiyou NF	19
Southern Cascades	44	Six Rivers NF	37
Central Sierra	127	Klamath NF	22
Southern Sierra	50	Shasta-Trinity NF	44
		El Dorado NF	34
		Stanislaus NF	41
		Yosemite NP	13
		Sierra NF	39
		Sequoia-Kings Canyon NP	8
		Sequoia NF	42

Table 2. Frequencies of detection of selected species of carnivores and marsupials* for the entire region (total) and the Klamath (1996-1997), Southern Cascades (1999), Central Sierra (1996-1999) and Southern Sierra (1998-1999) study areas.

	SPGR	MAPE	MAAM	MEME	MUSP	TATA	GUGU	URCI	CASP	VUVU	URAM	BAAS	PRLO	DIVI	FESP
TOTAL															
Number of sample units with detections	108	62	31	40	37	1	0	101	10	0	186	48	5	19	10
Percent of sample units with at least 1 detection	36.1	20.7	10.4	13.4	12.4	0.3	0	33.8	3.3	0	62.2	16.1	1.7	6.4	3.3
Total detections	872	384	265	155	94	1	0	938	38	0	778	329	7	93	16
KLAMATH															
Number of sample units with detections	46	29	5	4	12	0	0	29	0	0	61	20	0	1	1
Percent of sample units with at least 1 detection	59.0	37.2	6.4	5.1	15.4	0	0	37.2	0	0	78.2	25.6	0	1.3	1.3
Total detections	371	215	49	6	25	0	0	266	0	0	297	146	0	3	3
SOUTHERN CASCADES															
Number of sample units with detections	11	4	6	5	6	0	0	9	1	0	24	1	1	1	1
Percent of sample units with at least 1 detection	25.0	9.1	13.7	11.4	13.6	0	0	20.5	2.3	0	54.5	2.3	2.3	2.3	2.3
Total detections	61	14	33	8	14	0	0	65	2	0	67	7	2	2	1
CENTRAL SIERRA															
Number of sample units with detections	60	13	15	34	13	1	0	70	9	0	92	25	4	17	6
Percent of sample units with at least 1 detection	47.2	10.2	11.8	26.8	10.2	0.8	0	55.1	7.1	0	72.4	19.7	3.2	13.4	4.7
Total detections	339	26	92	122	28	1	0	563	29	0	188	140	5	81	6
SOUTHERN SIERRA															
Number of sample units with detections	17	22	10	5	9	0	0	11	1	0	41	9	0	2	2
Percent of sample units with at least 1 detection	34.0	44.0	20.0	10.0	18.0	0	0	22.0	2.0	0	82.0	18.0	0	4.0	4.0
Total detections	101	129	91	19	27	0	0	39	7	0	226	36	0	7	6

* SPGR = western spotted skunk, MAPE = fisher, MAAM = marten, MEME = striped skunk, MUSP = weasel, TATA = badger, GUGU = wolverine, URCI = gray fox, CASP = unknown canid, VUVU = red fox, URAM = black bear, BAAS = ringtail, PRLO = raccoon, DIVI = opossum, FESP = unknown felid.

Table 3. Number of sample units with detections of selected species of carnivores* on National Forests and National Parks.

	SPGR	MAPE	MAAM	MEME	MUSP	URCI	URAM	BAAS
Siskiyou NF	19	1	3	0	0	3	12	4
Six Rivers NF	14	18	2	0	10	16	29	10
Klamath NF	13	10	0	4	2	10	20	6
Shata-Trinity NF	11	4	6	5	6	9	24	1
Eldorado NF	9	0	2	8	1	11	21	3
Stanislaus NF	12	0	1	12	4	22	19	5
Yosemite NP	7	2	3	0	1	4	10	2
Sierra NF	9	7	4	6	5	17	24	8
Sequoia-Kings Canyon NP	3	1	3	0	1	1	6	2
Sequoia NF	14	21	7	5	8	10	35	7

* SPGR = western spotted skunk, MAPE = fisher, MAAM = marten, MEME = striped skunk, MUSP = weasel, URCI = gray fox, URAM = black bear, BAAS = ringtail.

Table 4. The statistical power to detect specified decreases or changes (increase or decrease) in the proportion of sample units with a detection, for fisher and spotted skunk. Estimates are based on Monte Carlo simulations developed by Zielinski and Stauffer (1996) using the strata estimates presented in Figure 11 and assuming 110 sample units in each of 5 stratum.

Magnitude of change		Fisher	Spotted Skunk
20%	decrease	0.77	0.87
	change	0.50	0.73
30%	decrease	0.91	0.99
	change	0.69	0.96
40%	decrease	0.99	-----
	change	0.96	-----

Sample Units Completed

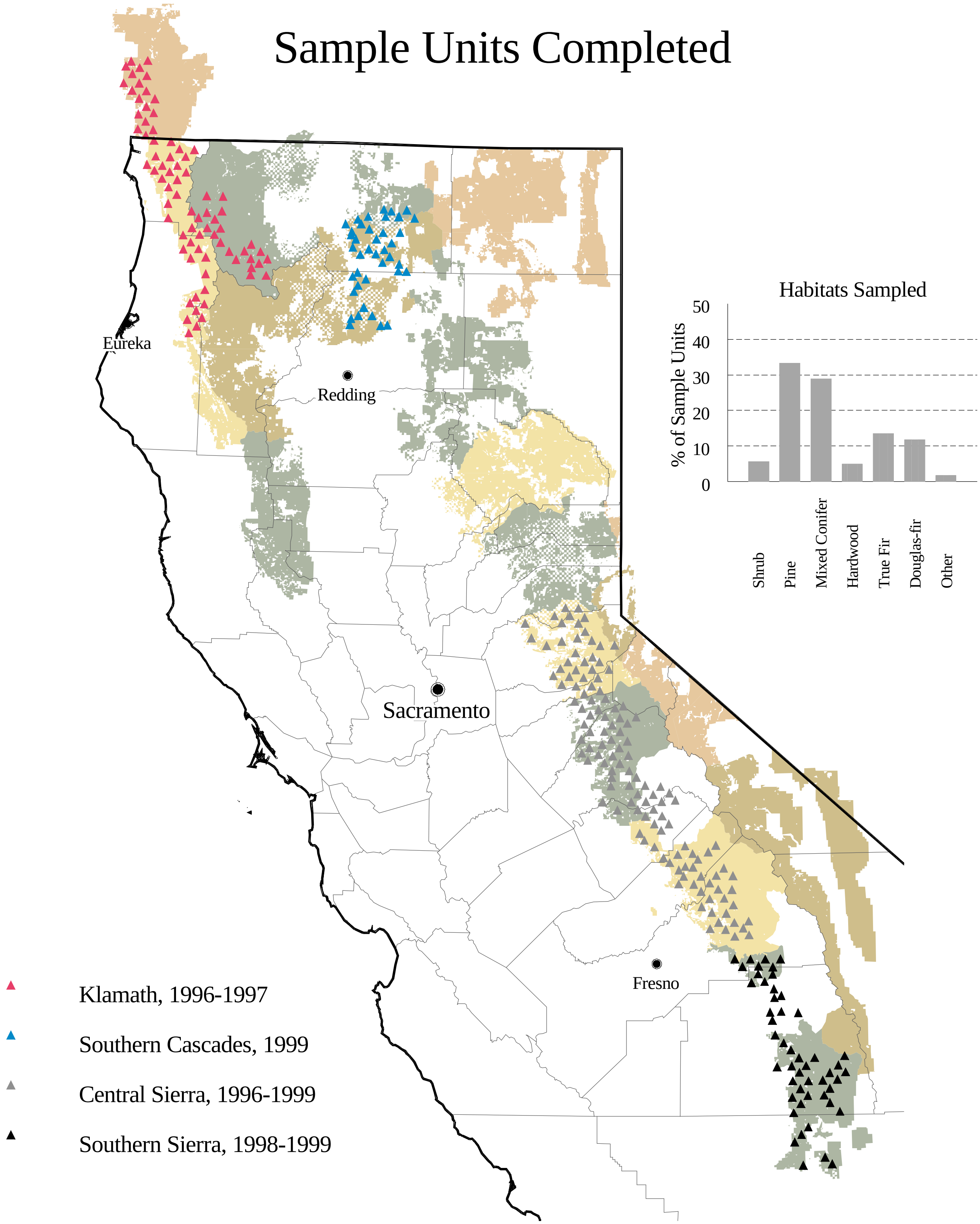

Figure 1. Locations that have been sampled in California and southwestern Oregon. The color of the symbol reflects the study area and year in which the survey was conducted. The inset ("Habitats Sampled") illustrates the distribution of sample units on the basis of 7 grouped California Wildlife Habitat Relationships (CWHR) categories. Shaded areas are national forests.

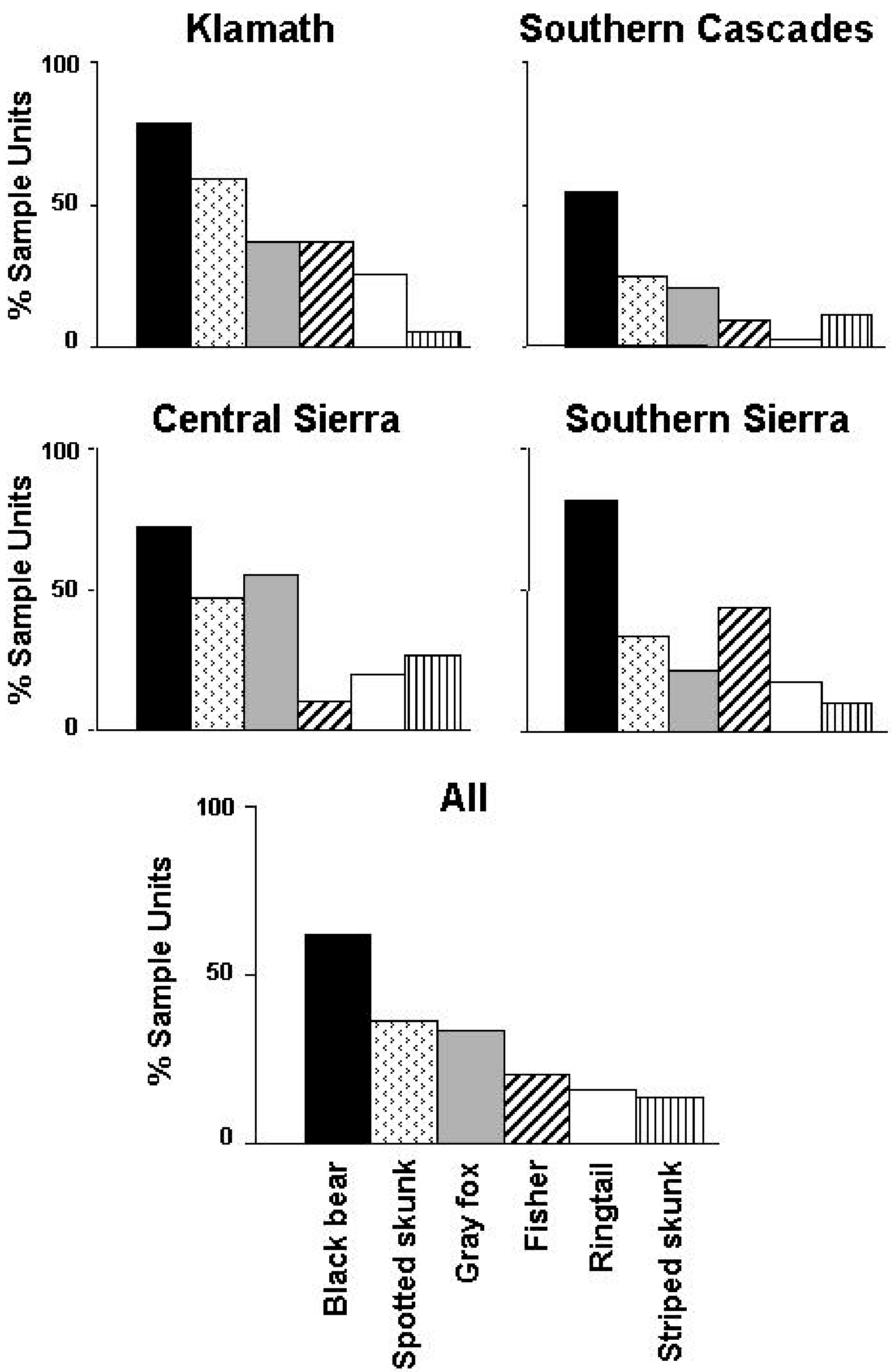

Figure 2. Percent of sample units at which the 6 most commonly detected species occurred, by region.

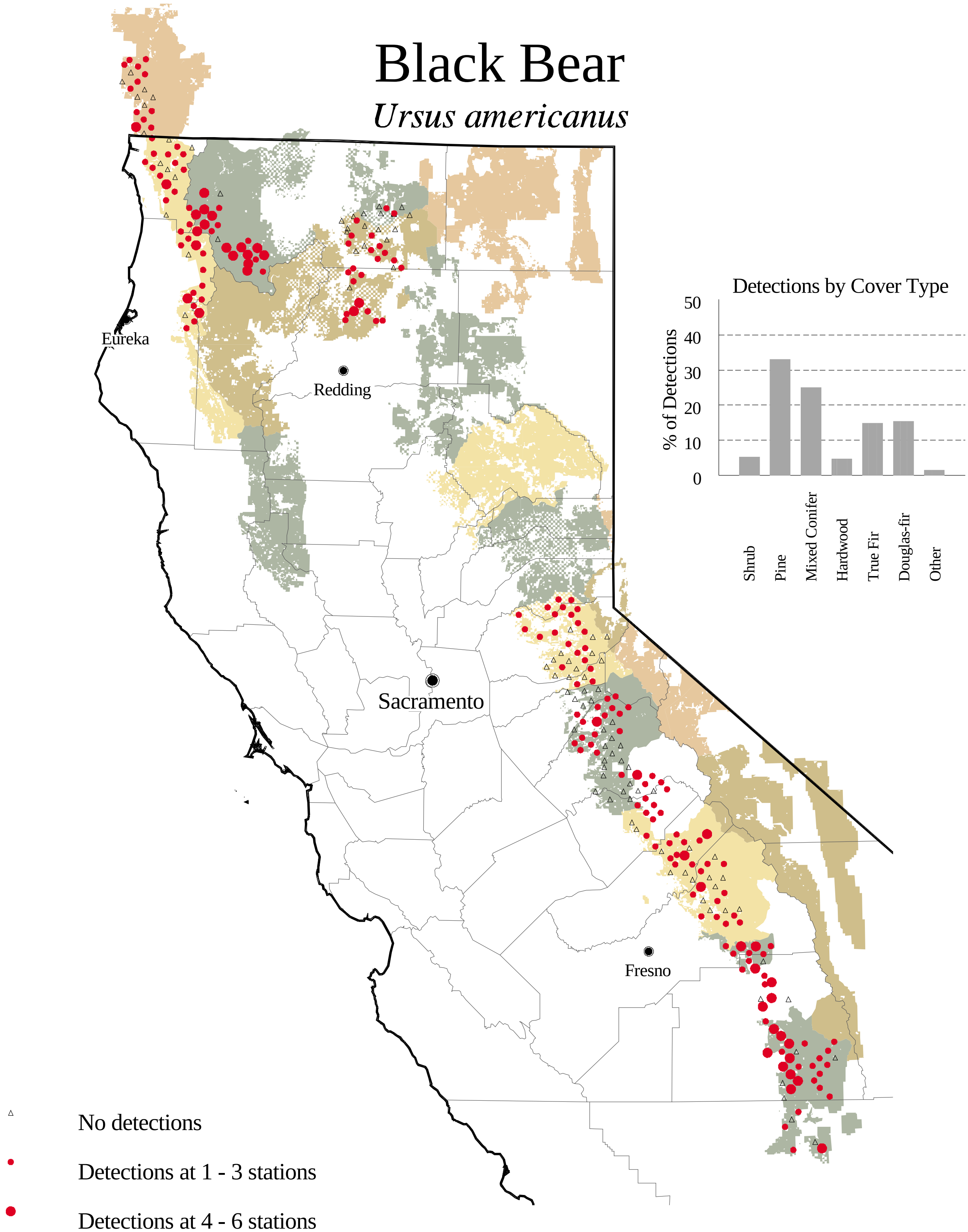

Figure 3. Locations where black bears were detected (circles) and not detected (triangles). The size of the circle is a function of the number of stations within each sample unit that received a detection (ranging from 1 - 6 track plate stations). Camera detections were not included in this count except for the rare case when a bear was detected only at the camera station. In these cases the symbol is the same as for a single track plate detection. The inset ("Detections by Cover Type") illustrates the percent of detections that occurred in each of 7 grouped California Wildlife Habitat Relationships (CWHR) categories. Shaded areas are national forests.

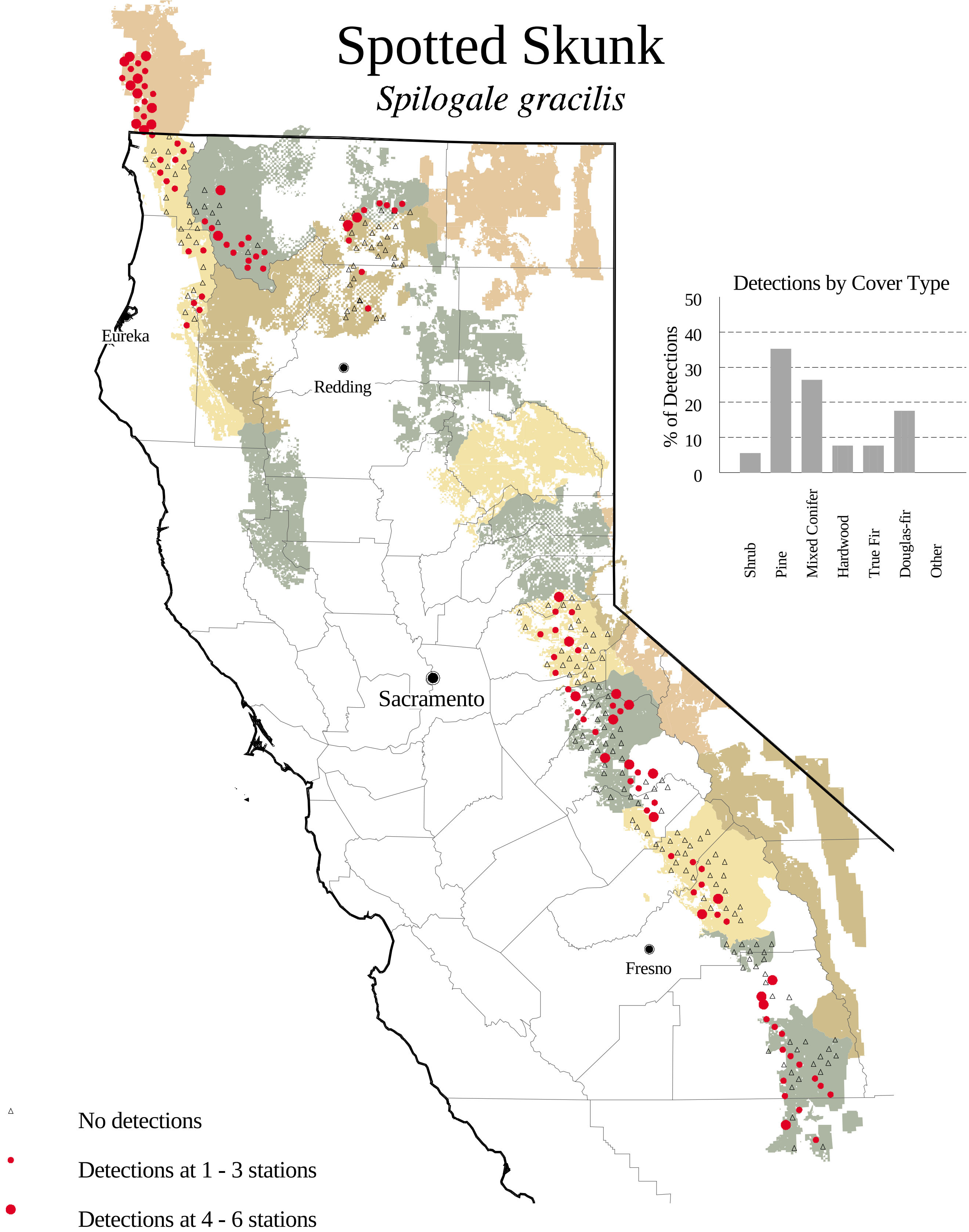

Figure 4. Locations where spotted skunks were detected (circles) and not detected (triangles). See legend for Figure 3 for details.

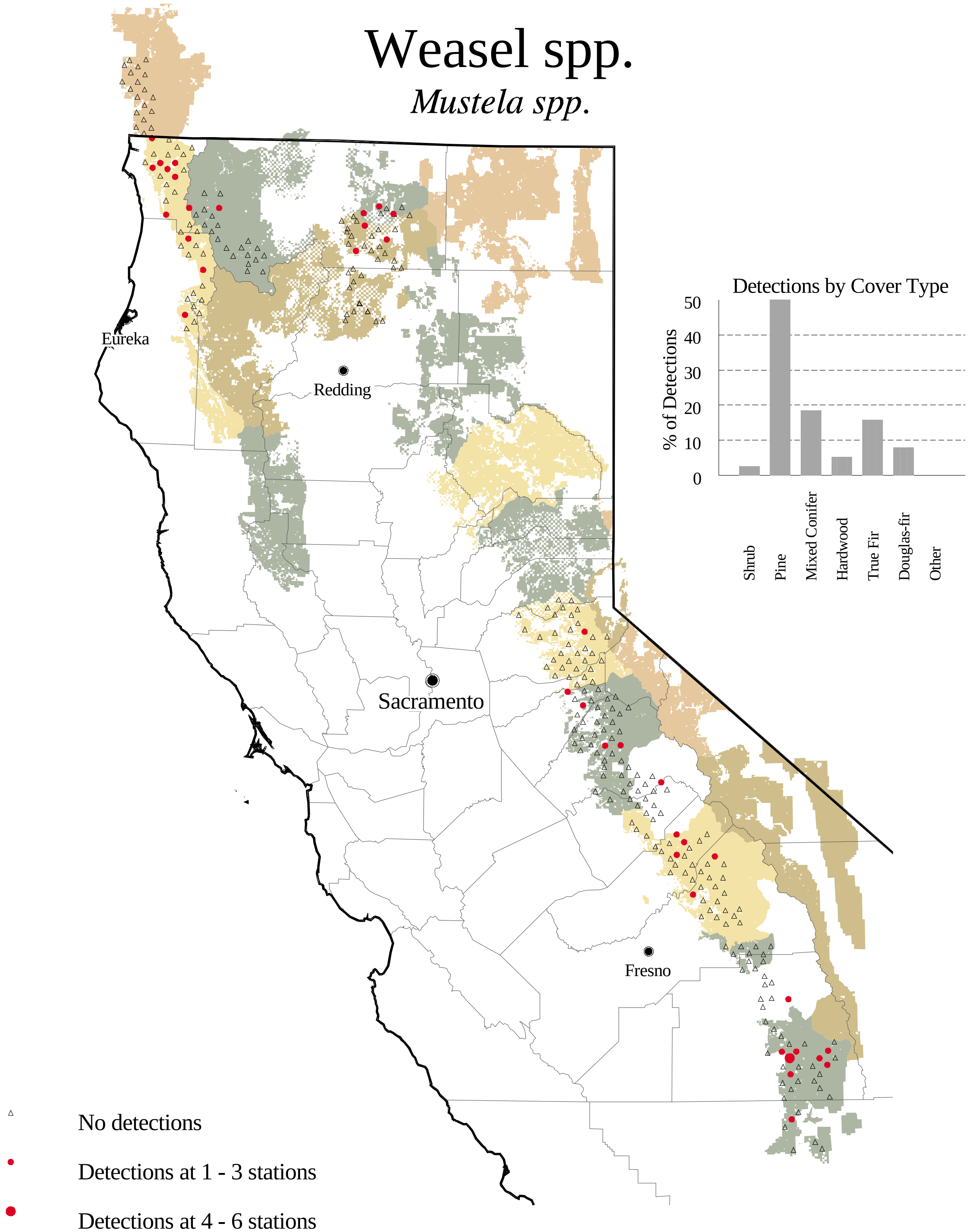

Figure 5. Locations where weasels (*Mustela* spp.) were detected (circles) and not detected (triangles). See legend for Figure 3 for details.

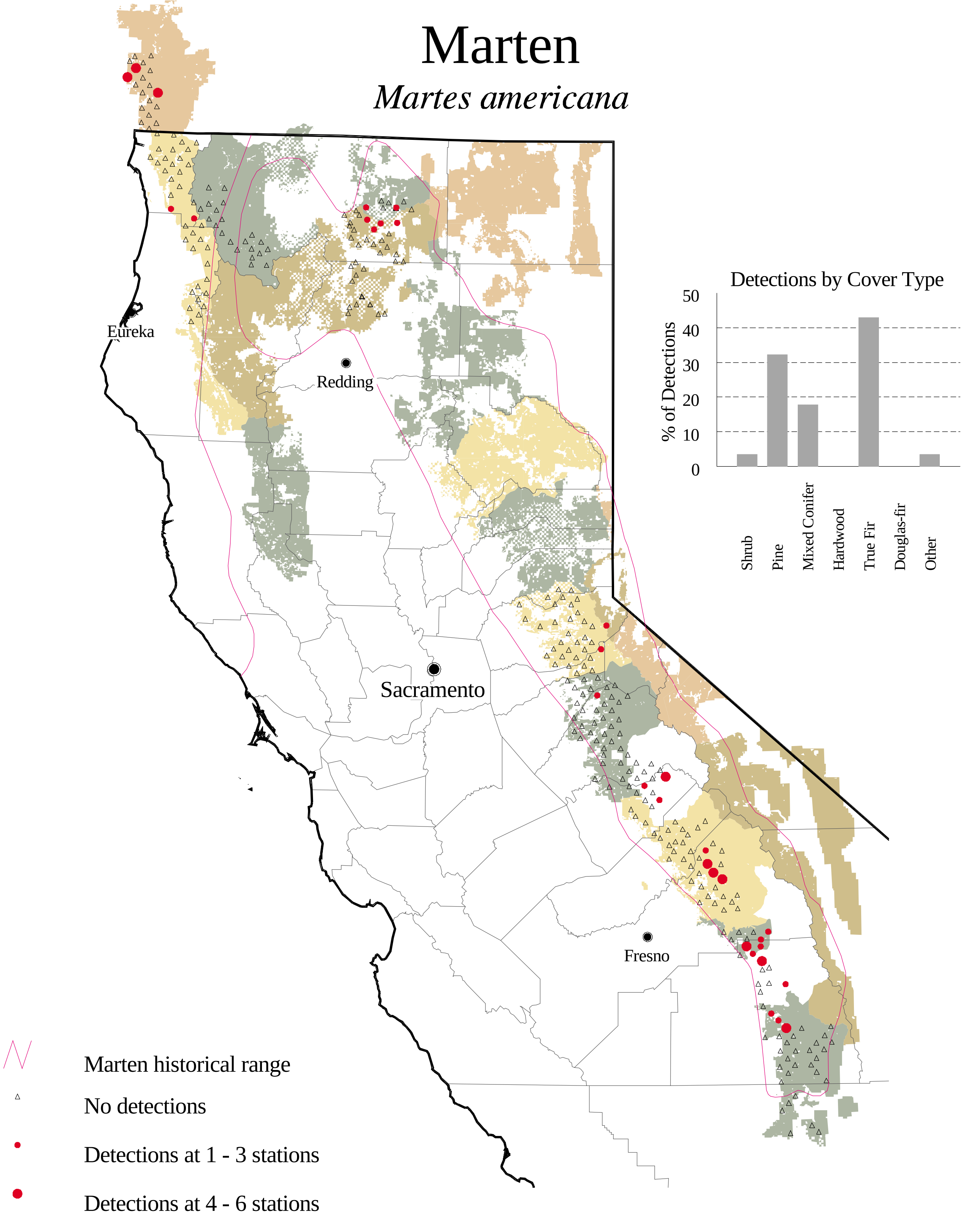

Figure 6. Locations where martens were detected (circles) and not detected (triangles). See legend for Figure 3 for details.

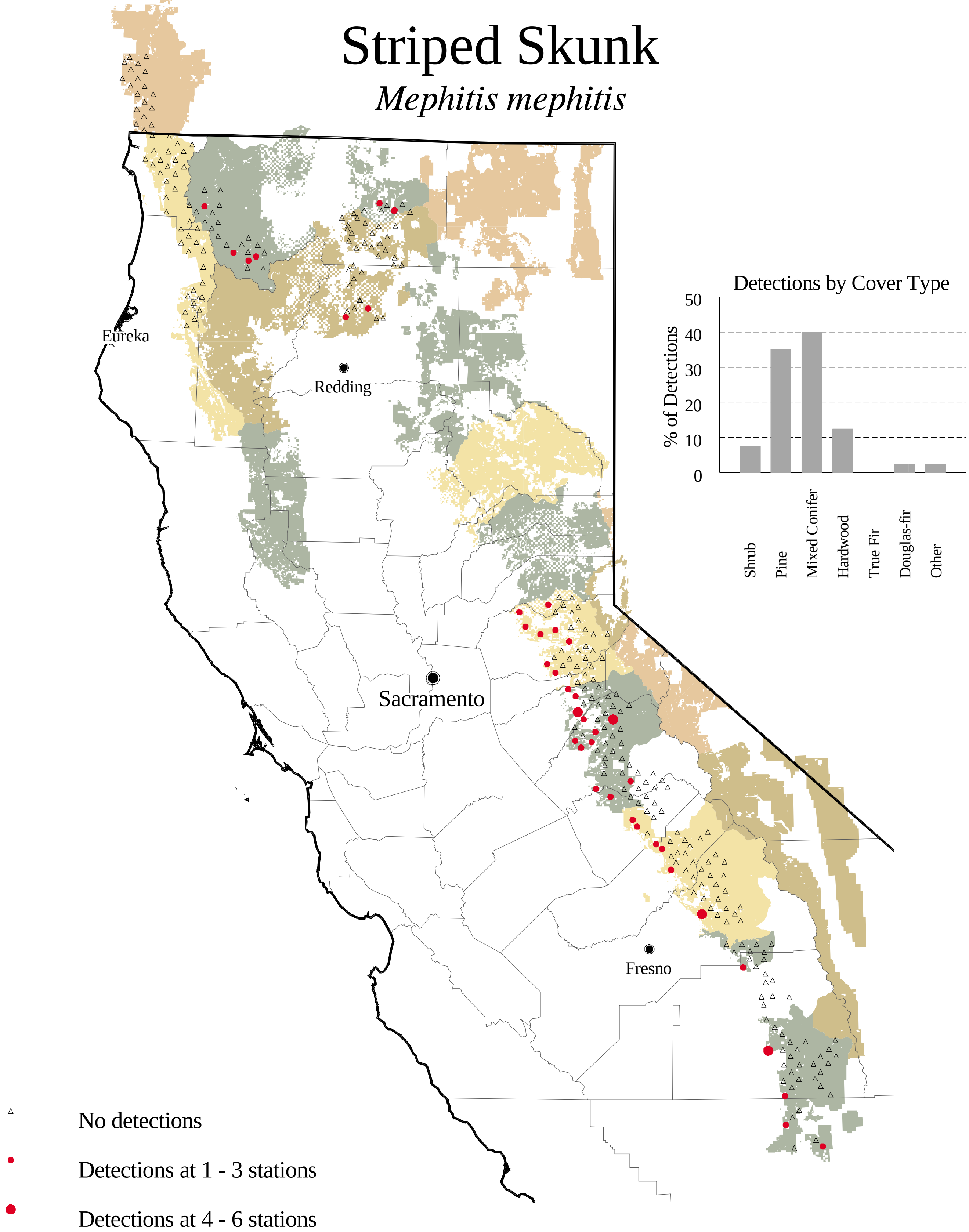

Figure 7. Locations where striped skunks were detected (circles) and not detected (triangles). See legend for figure 3 for details.

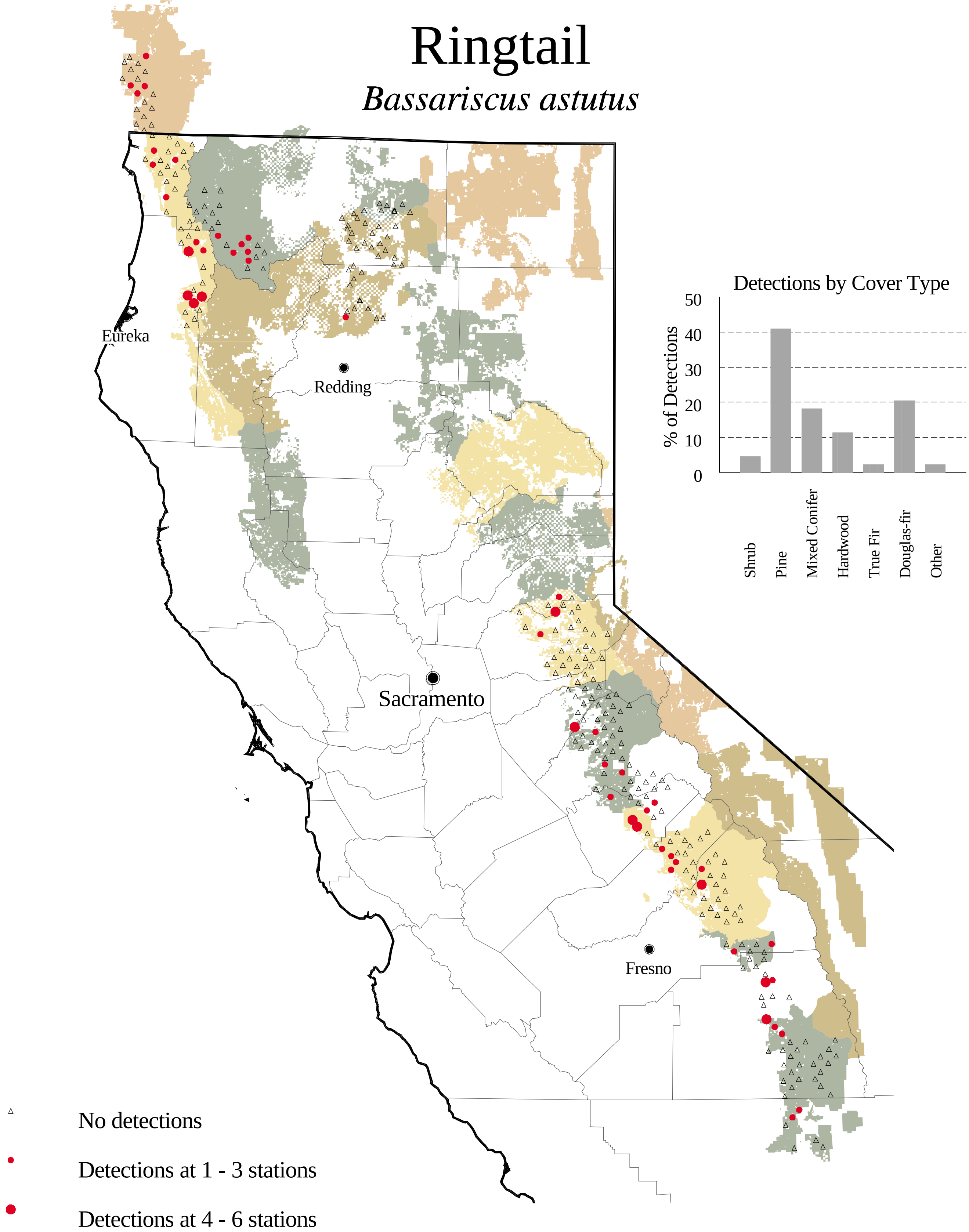

Figure 8. Locations where ringtails were detected (circles) and not detected (triangles). See legend for figure 3 for details.

Gray Fox

Urocyon cinereoargenteus

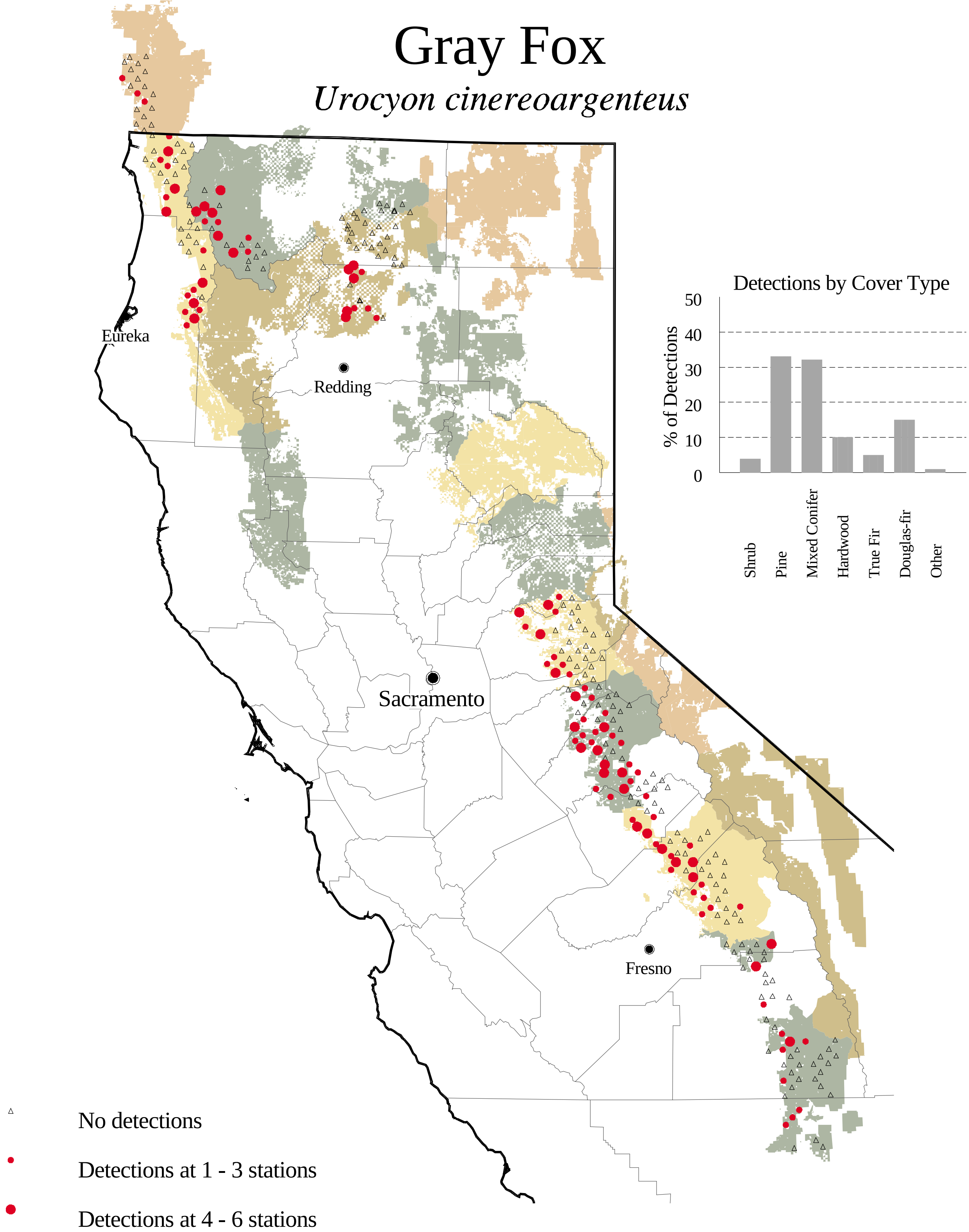

Figure 9. Locations where gray foxes were detected (circles) and not detected (triangles). See legend for Figure 3 for details.

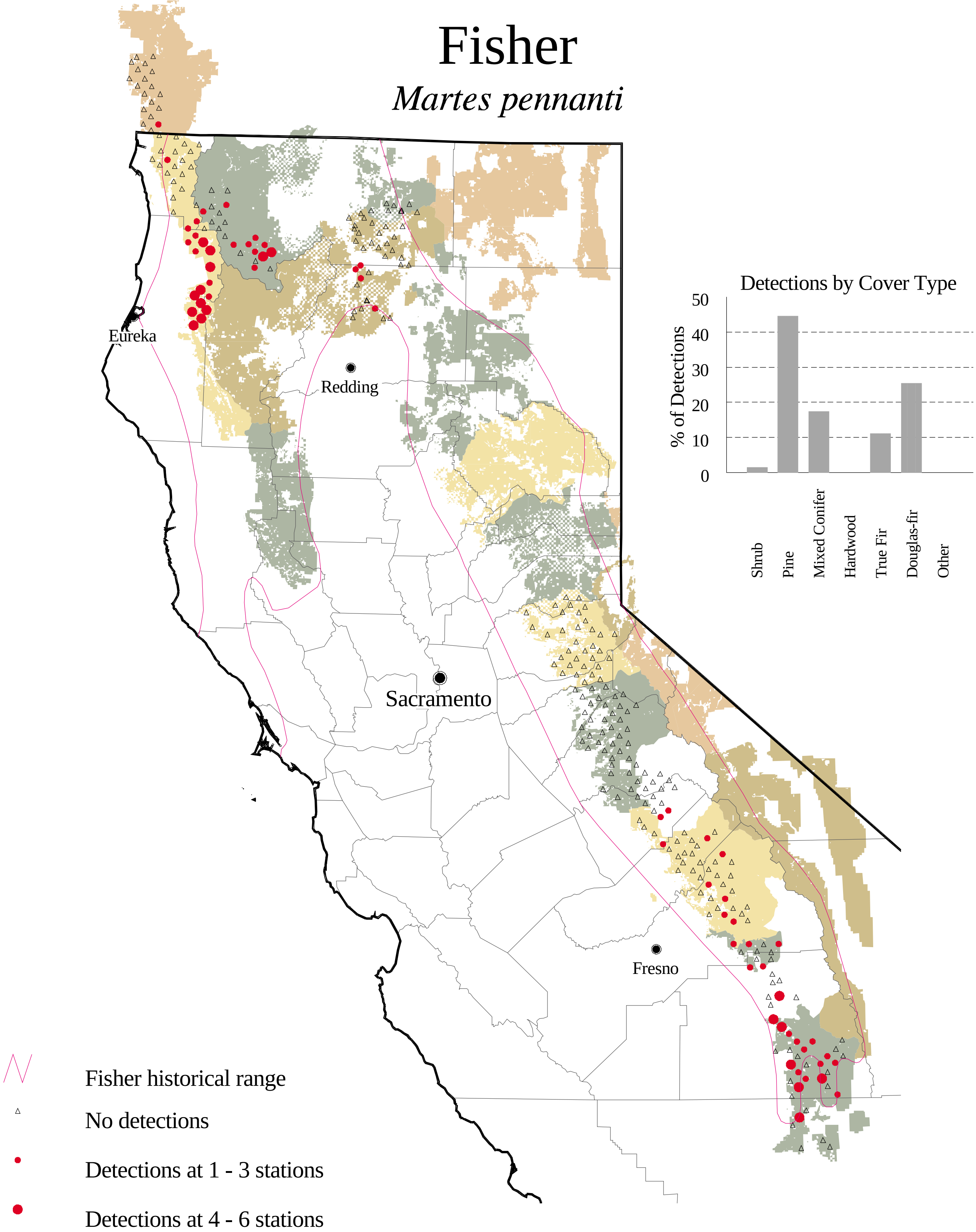

Figure 10. Locations where fishers were detected (circles) and not detected (triangles). See legend for Figure 3 for details.

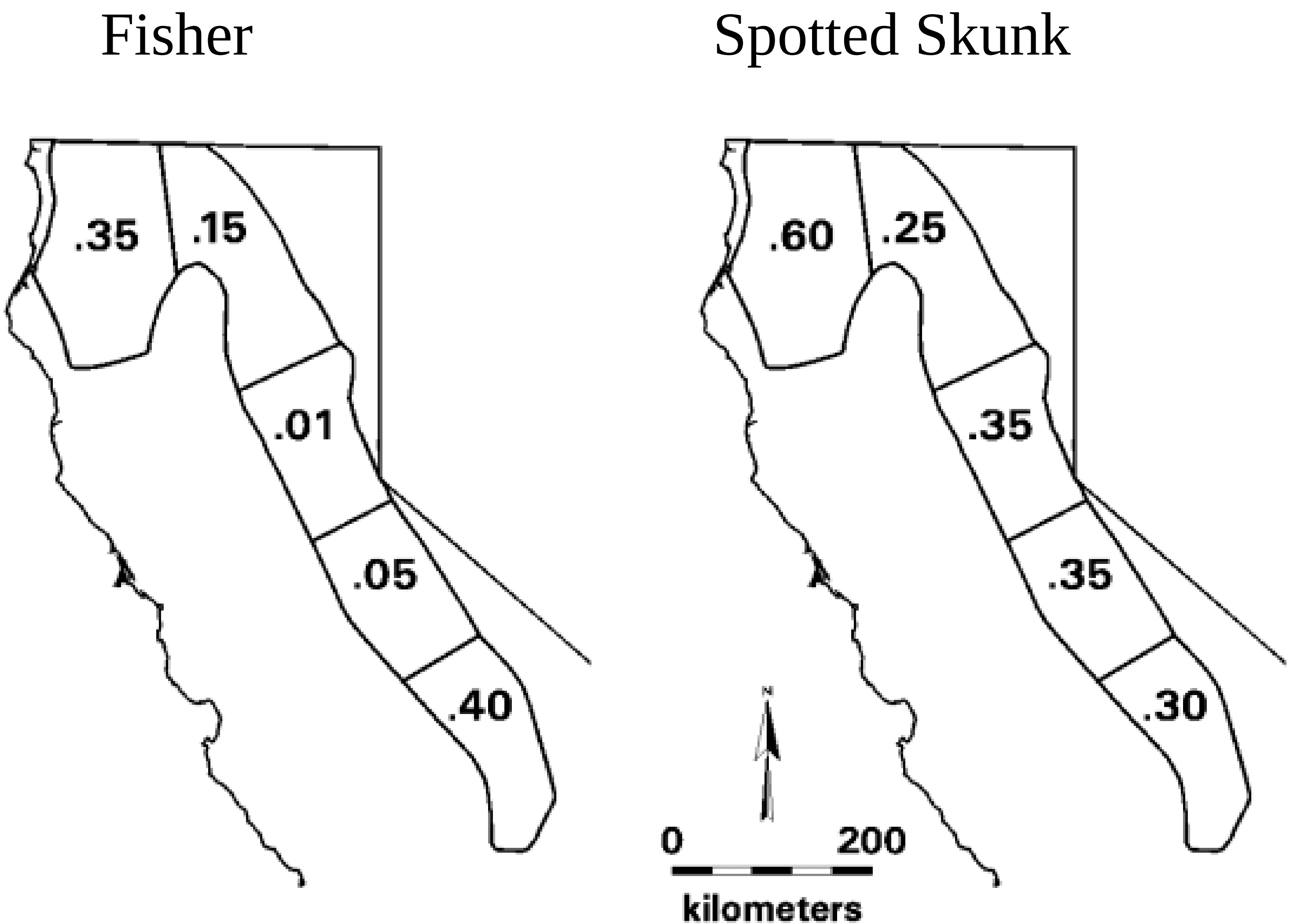

Figure 11. The proportions of sample units in each of 5 strata of the primarily forested area of northern California (as in Zielinski and Stauffer 1996) that are expected to detect fishers and spotted skunks.