Status and Estimated Size of the Only Remnant Population of the Humboldt Subspecies of the American marten (*Martes americana humboldtensis*) in Northwestern California

25 November, 2009

Final Report

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ABSTRACT

The Humboldt marten (*Martes americana humboldtensis*) has been extirpated from >95% of its historical range and is known from only a single population. To monitor the status of this population we resurveyed 28 sample units that were occupied by martens in 2000-01. In doing so, we sought to determine whether the occupancy rate in 2008 was the same or less than in 2000-01 (a one-tailed alternative hypothesis). To ensure our resurvey effort was capable of detecting a decline, if in fact it occurred, we conducted a prospective power analysis. This analysis identified that 7 additional sample units with suitable habitat were needed, for a total of 35, to be surveyed in order to detect a ≥29% decline with 80% power. We were unable to determine if the population had increased because in 2008 we sampled mostly sample units where martens were detected in 2000-01. We also attempted to estimate population size using DNA fingerprinting from hair captured by retrofitting track plate boxes with hair snaring devices. Other than adding the hair snare devices to track plates, each sample unit was resurveyed following the original protocol; two track boxes spaced 200m apart, sampled for 16 consecutive days and visited every other day to replenish bait and remove tracks. From June-August 2008 we resurveyed 30 of the original 35 sample units; 5 were inaccessible due to a wildfire that started in June. We used robust design multi-season occupancy modeling to determine the status of the population. To account for detection heterogeneity, and test hypotheses on how landscape habitat characteristics influence sample unit occupancy status, we developed 15 candidate models. Because there was no clear top model, we used model averaging to generate estimates for each parameter in the models. Detection probability (P) for the survey protocol was high in both 2000-01 (P = 0.92, SE = 0.02) and 2008 (P = 0.95, SE = 0.01). The occupancy estimate (ψ) for 2000-01 (ψ = 0.79) was significantly higher than that for 2008 (ψ = 0.46). The change between 2000-01 and 2008 marks a significant decline in site occupancy, equaling a change in occupancy rate (λ) = 0.58 (SE = 0.13, 95% CI = 0.31 to 0.81) or a 42% decline in sample unit occupancy over the 7 year period. Habitat covariates did not greatly improve model performance, however, sample units with more old growth in their vicinity were more likely to have stable marten occupancy between 2000-01 and 2008. In addition to the resurvey sample units, we surveyed 15 new locations outside the original survey grid, detecting martens in 3 new locations. Notably, one detection extended the known distribution 11 km to the south and another extended it 4 km to the north. The hair snares performed poorly, providing quality DNA samples on only 19% of marten visits to track plate stations; thus we could not estimate the population size using these data in a mark-recapture analysis. We used multi-state occupancy modeling to provide a secondary population estimate. Estimates from model averaging for the population size are 31.5 (95% C.I = 24-40) in 2000-01 and 20.2 (95% C.I = 11-30) in 2008. However, because the sampling grid did not sample all potentially occupied habitat, within and outside the grid, our most realistic estimates are double these sizes. The cause of the decline in occupancy is unknown and we cannot determine whether it is part of a natural population fluctuation or whether it is related to human-caused factors. Given that the most optimistic population estimate is <50 individuals in 2008, conservation actions to benefit this remnant population are needed immediately. Specifically, a population monitoring and research program should

be established to update the information presented here and to determine whether the causes for decline are natural or due to human-caused factors.

INTRODUCTION

Background

The Humboldt marten (*Martes americana humboldtensis*) was feared extinct (Zielinski and Golightly 1996) until 1996 when a marten was detected in the north-central portion of the historical range (Zielinski et al. 2001). Despite extensive survey efforts throughout much of the historical range, only a single small population of martens has been documented to occur, occupying an area representing <5% of the subspecies' original range (Slauson and Zielinski 2004). Recent survey efforts in the southern portion of the historical range failed to detect martens in coastal (Douglas and Holley 2009) and interior Mendocino county (Slauson and Zielinski 2006a), strengthening the case for this being the only population remaining in the historical range.

The first autecological studies on this population have yielded important information about the habitat use, diet, types of resting structures used, and home range size and habitat composition (Slauson and Zielinski 2006b, Slauson and Zielinski 2007, Slauson et al. 2007, Slauson and Zielinski 2009). Importantly these studies have revealed that martens in California coastal forests occupy low elevation areas with little or no snowfall and select forest habitats with some distinctly different features (e.g., dense, spatially extensive shrub cover) than Sierran martens (*M. a. sierrae*). Furthermore, Humboldt martens utilize two distinct types of fog-influenced forest habitats, Old Growth Douglas-fir (*Psuedotsuga menzesii*) dominated forests (hereafter non-serpentine habitats) and mixed conifer (e.g., Douglas-fir, Sugar pine [*Pinus lambertiana*], Western white pine [*P. monticola*], Lodgepole pine [*P. contorta*]) forest occurring on serpentine soils (hereafter serpentine habitats). This highlights the importance of conducting region-specific studies to provide managers with the best information to guide management efforts to conserve and restore marten populations.

The American marten is a 'Sensitive Species' in Region 5 of the Forest Service (Macfarlane 1994), a 'Species of Special Concern' for the California Department of Fish and Game (Bryliski et al. 1997), and was recognized as a priority species in FY2007 for the Region 5 Sensitive Species Program. The Forest Ecosystem Management Scientific Analysis Team (USDA, USDI, USDC 1993) gave the American marten the second-poorest score among mammals for the assessment of their habitat and distribution under option 9, with only a 67% likelihood of remaining well distributed (category A) and a 27% likelihood of becoming locally restricted (category B). In reality, the situation is far worse, martens on federal lands in the Coast Range of California are restricted to a single refugia (category C) and have been extirpated from a significant portion (>95%) of their historical range. Within their last stronghold, measures including the protection of Riparian Reserves, Late-Successional Reserves, northern spotted owl and marbled murrelet conservation measures, do not completely protect the population. At least 38% of the distribution of martens in the remnant population in coastal California occur outside of the reserves identified in the Northwest Forest Plan (USDA, USDI 1994, Slauson 2003), which suggests that this vulnerable population may not be receiving the protection that may be necessary to ensure its persistence and growth.

It has been 7 years since the distribution of the marten population was first assessed, and given the conservation concern, a new assessment of its status is necessary. We initiated a new research effort with 3 objectives: (1) to assess the population status and trend over the last 7 years, (2) estimate the population size, and (3) expand the survey effort to include adjacent areas with suitable habitat that have not been surveyed. Our objective is to determine the current trend and future response of this population to natural disturbance and forest management activities. Estimation of population size will allow for the assessment of population viability and to more accurately measure and predict the effects of management alternatives on the future persistence of the population.

METHODS

Population Status and Trend Assessment

There were several alternative approaches to designing the population status assessment. These alternatives included: (1) complete resample of all sample units from 2000-01, (2) resample a random subset of the sample units from 2000-01, (3) resample all sample units where martens were detected or where suitable habitat exists but martens were not detected. Alternative 1 is by far the most expensive approach and due to the limited distribution of suitable habitat in the study area, would spend a high proportion of funds in areas with a very low probability of supporting martens (Slauson et al. 2007). Alternative 2 is a less expensive approach, but because only ~20% of the 159 sample units supported martens in 2000-01, is a risky design for obtaining an accurate estimate of status if the proportion of sample units that supported martens in 2000-01 or suitable habitat are underrepresented. Alternative 3 is the least expensive and focuses only on sample units with prior occupancy by martens or with suitable habitat to support martens. Alternative 3 limits the ability to detect *increases* in occupancy if the proportion of previously unoccupied sample units selected is small. Based on the cost-efficiency, the focus on sample units with suitable habitat, and that from a conservation perspective the main objective was to determine whether the population was stable or declining, we selected the design from alternative 3.

For the status and trend assessment, it was essential to determine, *a priori*, the probability of detecting significant decline and to choose an adequate sample size to be able to detect change with an acceptably high confidence. The null hypothesis, that there has been no change in the population index over a 7-year period, must be tested against the alternative that the population has decreased (one-tailed test). We conducted a prospective power analysis to help guide the selection of the optimal number of sample units to survey in order to detect a decline, if it had occurred, in population distribution (occupancy) with 80% power ($\beta = 0.2$) and an $\alpha = 0.2$; where α is the probability of a Type I error, accepting that a decline has occurred when it has not occurred, and β is the probability of a Type II error, rejecting a decline when it has in fact occurred.

We calculated statistical power using a program written by one of the authors (JB) that used parameter estimates from field data. For field data we used the data collected from the same study area (Slauson et al. 2007). We simulated a 20% decline in occupancy over a 7-year period for a one-tailed test. To parameterize the analysis, we used the probability of detection for the survey protocol estimated from the 2000-01 survey protocol (P = 0.89; Slauson et al. 2007), and the total number of sample units with observed marten detections (n = 28) in 2000-01, as the first two parameters. Second, we selected an initial occupancy rate (ψ) = 0.8 because when sample sizes are small, it becomes difficult to detect lower levels of change (e.g., <50%) in ψ when the initial occupancy rate is lower. With this parameterization, we determined that 7 additional samples units, for a total of 35, would be required to be able to detect a ≥29% decline with 80% power and an $\alpha = 0.2$. We selected the 7 additional sample units within the largest patches of suitable habitat available in the 2000-01 survey grid where martens were not detected in 2000-01.

We re-sampled the sample units from the original 2000-01 sampling effort where martens were detected (n = 28 points; Slauson et al. 2007) and where predicted habitat suitability is highest (n = 7 points; both within the original survey grid and adjacent areas surveyed in 2000-01) to determine whether the population has remained stable or has decreased (Figure 1). To predict habitat suitability we used the top mixed-scale habitat model from Slauson et al. (2007). Selected sample units were resampled using the same protocol originally used in 2000-2001 (Slauson et al. 2007). This involved 2 track plate stations per sample unit, one established at the grid point and the second 200 m away but in the same forest stand. Track plates were baited with a single chicken drumstick and a commercial lure (Gusto, Minnesota Trapline Products, Pennock, MN) was applied at 2m on the nearest tree bole. Each track plate station was visited every other day for 16 consecutive days, replenishing bait and removing track sheets during each of 8 visits. We measured all the *Martes* tracks collected in 2000-01 and in 2008 using the track mensuration techniques of Slauson et al. (2008a) to distinguish between the tracks of males and females.

Occupancy Status and Trend Analysis

We used the robust occupancy estimation option in PROGRAM MARK (version 5.1) to estimate visit-specific detection probability (p) and the overall detection probability suing the survey protocol (P), time-specific occupancy rates (ψ_t) and trend in occupancy rates (λ). Time-specific estimates of ψ were compared using McNemar's Chi-square test. Multi-season occupancy modeling also allows for the estimation of the probabilities of extinction (ε) and colonization (γ). Because these two parameters measure the two agents of change in occupancy over time, we also evaluated the influence of several habitat variables (discussed below) on these two probabilities.

Detection Covariates

We evaluated potential sources of detection heterogeneity related to variation in marten detection by year (2000-01 versus 2008), between serpentine and non-serpentine habitat types, within survey duration (by visit-specific, weekly, and by grouping visits with higher and lower detection probabilities [hereafter called visit group]) by including them as covariates in competing models. These were also compared to a simple model assuming detection probability is constant across the 8-visit survey duration.

Habitat Covariates

We developed habitat covariates to be used only to evaluate how habitat characteristics influence the agents of occupancy change: extinction (ε) and colonization (γ). By including these habitat covariates we are evaluating whether the habitat covariates used explain differences between sample units where marten occupancy is constant or changing between the two time periods.

We developed 7 habitat covariates, representing home-range scale characteristics of the areas within a 1-km radius of each sample unit (Table 1). We used 3 GIS coverages to derive the habitat covariates. The first was a vegetation polygon coverage created by the Six River National Forest Ecology Program (hereafter EP layer), with habitat typing based on air photo interpretation and extensive plot sampling and ground truthing. This vegetation layer is highly accurate, with >90% of polygons correctly classified to vegetation series and seral stage (J. Hunter unpubl. data). Structured query language (SQL) was used to make selections from the vegetation coverages to describe marten habitat. Three different habitat types were derived from developmental stage information in the EP layer: old growth stage (OG), old growth and late mature stages (OGLM), and young forest, combining the shrub and pole developmental stages (YNG). A fourth category representing serpentine habitat (SERP), regardless of developmental stage, was derived from a soil coverage also created by the Six Rivers National Forest. The third coverage was a transportation layer, used to assess road density, that included all types of forest roads (e.g., paved, gravel, unimproved) was also created by the Six Rivers National Forest.

Each sample unit was buffered with a 1 km radius circle, capturing an area (314 ha) equivalent for a typical male marten home range in coastal California (Slauson and Zielinski unpubl. data) and the Sierra Nevada mountains (Spencer et al. 1981). Polygon coverages within each 1-km radius circle were converted to 30 m raster then processed with a spatial analysis program (FRAGSTATS v 3.3, University of Massachusetts Landscape Ecology Program, http:/www.umass.edu/landeco/research/fragstats/fragstats.html) to calculate landscape metrics associated with each grid point. These metrics included percent of habitat type (e.g., OG, YNG) in landscape (PLAND), and number of habitat type patches (NP). The linear amount of road within the circle was converted to kilometers and divided by the circle area to yield km/km^2.

Model Development, Selection, and Evaluation

We developed candidate models that incorporated detection covariates to explain variation in detection probabilities and habitat covariates to distinguish between sample units with stable and unstable occupancy over the two survey periods. We used a 2-step modeling process. The first step involved the development and comparison of multiple competing models to explain detection heterogeneity. The top ranked model(s) from this step were then used in an information-theoretic framework (Burnham and Anderson 2002) to develop an *a priori* set of competing models consisting of habitat covariates to attempt to distinguish between sites with stable versus unstable occupancy.

The second step involved the development of a small set of *a priori* models based on the careful consideration of potential biologically meaningful variables (Burnham and Anderson 2002). We developed conceptual models describing marten habitat selection based on existing information and our hypotheses about habitat selection in coastal forests of northwestern California. We then translated conceptual models into occupancy models using the selected variables. The resulting model set represented competing hypotheses about how habitat characteristics influence the processes of marten extinction or colonization in sample units. During model development, we constrained the number of additional covariates for extinction or colonization to 2 per model due to the limited sample size used for our analysis resulting in a set of 15 models. We ranked this set of models using Akaike's Information Criterion for small sample sizes, (AIC_c), (Burnham and Anderson 2002). We interpreted models by the comparison of ΔAIC_c values, which provides a measure of strength of evidence and a scaled ranking for candidate models (Anderson et al. 2000). To further interpret the relative importance of a model, given the a priori model set, we calculated Akaike weights (w_i) using ΔAIC_c values and created a 95% confidence set of models by considering all models whose cumulative weights equaled 0.95 (Burnham and Anderson 2002).

To assess the relative importance of each variable in the selected models, we calculated their adjusted importance weights (Anderson et al. 2001). Because we considered more than one model when making inferences about the data, we also assessed the importance and interpretation of each variable by examining the range and direction of coefficient values for variables in the top ranked best model(s).

Population Size Estimate

To estimate population size we deployed hair snare devices inside each track plate boxes to collect hairs from martens that entered them (Zielinski et al. 2006).
Hair samples were sent to the USDA Forest Service Rocky Mountain Research Station's Carnivore Genetic Laboratory to extract DNA and conduct individual identification from DNA. The track plate hair snare protocol contains 8 capture occasions where individuals

can be identified over the survey duration. The 'capture' data derived from the hair snares were used to estimate individual and gender-specific capture probabilities and to estimate population size using mark-recapture methods (White et al. 1982). This method assumes that the population is closed, such that the population size of martens does not change within the survey season. By selecting the summer months (Jun-Aug) prior to juvenile dispersal, this assumption is likely valid.

We also estimated population size using multi-state occupancy modeling. While we acknowledge that this is not a standard approach for population estimation, we believe that our sampling design met the key assumptions to make this a plausible approach. Furthermore, by estimating population size using both methods, we can then evaluate the efficacy of the multi-state occupancy method for population estimation compared to the mark-recapture estimate. For the multi-state occupancy approach to be valid for population estimation, sample units must be both independent with respect to the detection of individual male and female martens and detection of individuals between adjacent sample units. For example if >1 male is typically detected at a sample unit or males typically are detected at >1 sample unit, the estimate of the population size will be biased low and the precision of the estimate biased high. To explicitly evaluate the relationship between the number of individuals detected within each gender at sample units, we compared the number of individual martens captured at each sample unit using live-traps in 2000-01 and hair snaring in 2008 to the number of individuals identified at each sample unit from gender identification. Our previously collected home range data (Slauson and Zielinski unpul. data) verified that the sample units used here were likely spatially independent because only 1 of 13 individual martens had a home range large enough to encompass the area of >1 sample unit. Finally we also evaluated whether any individual, identified using live capture or hair snaring, was captured at more than one sample unit. We then used the results of these comparisons to evaluate the accuracy of the analysis and, if necessary, calibrate the analysis.

For the multi-state approach, a sample unit could exhibit one of 4 occupancy states: absence, male-only occupancy, female-only occupancy, and male and female occupancy. For each observed state, detection histories were created and state-specific estimates of ψ were generated (Table 2). We used single-season, multi-state modeling because our dataset was not large enough to reliably estimate all the additional parameters using the multi-season, multi-state approach. We developed and evaluated several candidate models (Table 2) for each 'season' of data (2000-01, 2008) to explain variation in gender-specific detection probabilities using the same methods described previously (see Model Development, Selection, and Evaluation). We used the state-specific estimates of ψ from the top ranked model to estimate population size using the following equation:

$$\hat{N} = n \cdot (\hat{\psi}_M + \hat{\psi}_F + 2\hat{\psi}_{MF})$$

Where n is the number of sample units. To estimate the 95% confidence interval for this estimate, based on the variances and covariances of the occupancy estimates, we used the following equation:

$$\hat{N} \pm 1.96 \cdot \sqrt{\hat{\sigma}_M^2 + \hat{\sigma}_F^2 + 4\hat{\sigma}_{MF}^2 - 2\hat{\sigma}_{M,F} - 4\hat{\sigma}_{M,MF} - 4\hat{\sigma}_{F,MF}}$$

Expansion Surveys

To further define the distribution of martens in the study region, we surveyed additional locations both within and outside the original grid. To guide sample unit placement outside the original grid, we extended the 2-km grid beyond its original extent by 10 km in all directions. Field maps were used to identify suitable locations with patches of Old Growth, Late Mature, and Serpentine habitat, and site visits were used to confirm the presence of dense, spatially-extensive shrub cover. In cases where suitable habitat was identified, but no sample unit point overlapped the suitable habitat patch, a new point was established. Surveys in either location followed the same objective: survey the largest patches of suitable habitat that have not been previously surveyed. Expansion sample units were surveyed using the sample protocol described previously for the re-survey of sample units.

RESULTS

Marten Detections

From 14 June to 17 August 2008 we completed surveys at 30 of the 35 original sample units and 15 expansion sample units (Figure 1). We were not able to survey 5 sample units that were chosen for resampling due to wildfire closures. Marten detections were observed at 14 (47%) of the 30 sample units in 2008 (Table 3, Figure 2). In 2000-01, marten detections were observed at 23 (76%) of the 30 sample units (Figure 2).

Marten detections were observed at 3 (20%) of the 15 expansion sample units. Two of these detections increased the known range ~11 km to the south to near Fish Lake in the Bluff Creek watershed and within 2 km of the Klamath River (Figure 3). The third detection increased the known range ~4km to the north to near the mouth of Rock Creek on the Smith River. Based on the addition of these new detection locations, the population occupies a total area of 637 km^2, using minimum convex polygon estimation. The other detection occurred in a sample unit established within the original survey grid, but which was placed in more suitable habitat than the original sample unit. At the 3 expansion sample units where martens were detected, males were detected at all 3 and females at only 1 sample unit. Other mesocarnivores were rarely detected in 2008, with the fisher being the most frequently detected at 5 (11%) of all 45 sample units (Table 3).

Hair Snares

Of the 18 total sample units where martens were detected in 2008, martens visited individual track plate stations on 47 visits. On only 4 (9%) of these visits did martens enter the track plate and not pass through the hair snare, suggesting martens were rarely repelled by the snare device. However, marten hair was only collected on 27 (57%) of the 47 visits, suggesting the snare design was not effective at capturing hair from martens passing through the snare.

Of the 27 marten hair samples collected, only 9 samples (33% of all hair samples, 19% of all marten visits) contained quality DNA for individual and gender analysis. Hair quantity was closely related to obtaining quality DNA, with 86% (6 of 7) of samples containing ≥10 individual hairs successfully amplifying while only 15% (3 of 20) of samples containing <10 individual hairs successfully amplified.

Of the 9 hair samples with quality DNA, 6 individuals (4M:2F) were identified from 4 sample units. Male and female martens were both detected at 2 sample units and only males were detected at 2 samples units. No individual was detected at >1 sample unit, which is consistent with our assumptions about spatial independence among sample units (see above).

Population Status and Trend

We developed and evaluated 15 competing models to estimate P, ψ, ε, and γ. Six models were highly competing (<2 ΔAIC_c) for the top model and together had only 72% of the w_i (Table 4). Each of these models used the visit group variable to model p, which best fit the data compared to all other variables used to model detection heterogeneity.

Because there was no clear top model, we used model averaging to generate estimates for each parameter in the models. Detection probability for the survey protocol (P) was 0.92 (SE = 0.02) in 2000-01 versus 0.95 (SE = 0.01) in 2008 and did not significantly differ (t = -1.31, df = 12, p = 0.207). The occupancy estimate (ψ) for 2000-01 (ψ = 0.79 (SE = 0.09, 95% CI = 0.56 to 0.92) was significantly higher than that for 2008 (ψ = 0.46, SE = 0.10, 95% CI = 0.28 to 0.66; McNemar's Chi-square Test: χ^2 = 45.3, df = 31, p = 0.046). The change between 2000-01 and 2008 at the 30 sample units marks a significant decline in sample unit occupancy, equaling a λ = 0.58 (SE = 0.13, 95% CI = 0.31 to 0.81) or a 42% decline in sample unit occupancy over the 7 year period. It follows, therefore, that the estimated probability of extinction (ε = 0.49, SE = 0.12) was higher than the probability of colonization (γ = 0.29, SE = 0.23).

Road Density and OG_Pland were the only habitat covariates that had an influence on the probability that a sample unit would go extinct from 2000-01 to 2008 (Table 4, 5). Martens were less likely to go extinct in sample units with *higher* road densities and *more* Old Growth. Specifically, a 1 km/km^2 increase in road density resulted in a 48% decrease in the probability of "extinction" (i.e., that a sample unit would be occupied in 2000-01 and not occupied in 2008), while a 30 ha increase in the amount of old growth resulted in a 37% decrease in the probability of extinction. Furthermore, the size of old growth patches encompassing sample units where marten occupancy remained constant between 2000-01 and 2008 was, on average, about 40% larger (mean = 78 ha, SE = 12 ha) than those that became unoccupied in 2008 (mean = 55 ha, SE = 15 ha; Table 6).

Population Size

The hair snare results were too poor to facilitate a population estimate using mark-recapture methods, so we only estimated population size using the multi-state occupancy method. There were 13 sample units where both capture (live trapping or hair snare) and detection results were available for direct comparison. The total number of martens identified between the capture and detection methods were equivalent (n = 18). The sex ratio identified from capture (11M:7F) was more male-biased than the sex ratio from detection (8M:10F). In only one of 13 (7.7%) sample units was more than one individual of the same gender captured. Finally, no individuals identified via capture in live traps or hair snares (n = 20) were captured at more than one sample unit, supporting the assumption that sample units are independent. These results suggest that the multi-state approach for population estimation using our sampling design should be valid.

We developed 4 competing models to estimate *P* and ψ for each sampling season and for 2000-01; the top model was well supported having 0.75 of the Akaike weight (Table 7). For 2008, the top model was not as well supported having only 0.50 of the weight (Table 7). The top model for 2000-01 had *p* modeled for each gender state, while the top model for 2008 had *p* modeled best by an increasing linear trend across all visits.

Using the parameter estimates from model averaging (Table 7), the population estimates for the 30 sample units used in this analysis are 31.5 (95% C.I. = 24-40) in 2000-01 and 20.2 (95% C.I. = 11-30) in 2008. Notably, female only occupancy declined the most substantially from 2000-01 ($\psi_f = 0.32$) to 2008 ($\psi_f = 0.06$) compared to either male only or dual gender occupancy in 2000-01($\psi_m = 0.39$, $\psi_{mf} = 0.16$) and 2008 ($\psi_m = 0.25$, $\psi_{mf} = 0.17$).

DISCUSSION

The magnitude of the decline in occupancy between 2000-01 and 2008 was not anticipated. There has been little change over the last 10 years to the vegetation characteristics of the landscape this population occupies. However, during the resurvey the Blue II fire burned through a number of areas where we detected martens immediately prior to the fire (Figure 4). Subsequent site visits to some of the burned areas have revealed that the dense understory has been removed, likely reducing the suitability of these sites over the short term. Overall, the fire burned 4 sample units (20% of the observed occupied range in 2008), 3 of which were occupied prior to the fire. Because, we did not incorporate these likely fire effects into our population trend, the decline in occupancy is likely higher than described.

We have considered whether there were any major differences between the 2000-01 survey and the 2008 survey that may have influenced the results. The 2000-01 effort did include surveys during months (Sept-Nov) where dispersing young of the year martens may have been present that were not included in the 2008 effort. However, only 4 sample units surveyed from Sept-Nov in 2000-01 did not remain occupied in 2008 reducing this concern. The only other major difference between survey years was the presence of the fires in 2008. We did not work in close proximity to actively burning areas, but the entire study area was engulfed in smoke from mid July through August. While we do not know how martens respond to smoke, we did not see any change in the visitation characteristics of martens after the fires began. We explicitly tested for this by using month as a covariate for modeling detection probability. Thus, although the two survey efforts did differ slightly with respect to the months when surveys occurred and the influence of smoke, we do not believe these affected our results.

The decline in sample unit occupancy appears to be more pronounced in serpentine habitats on the western edge of the population (Figure 3) and in sample units where the Old Growth vegetation type is highly fragmented. While we have documented reproduction and stable summer-fall home ranges occurring in serpentine habitats (Slauson and Zielinski unpubl. data), these new findings suggest these areas may be lower quality habitat for martens than Old Growth non-serpentine habitats. Due to their low productivity, serpentine habitats remain fairly unchanged due to timber harvest, with the exception of low levels of fragmentation due to road development. Alternatively, these habitats also occur along the western edge of the marten population, where the contact zone with intensively managed lands occurs and larger-bodied mesocarnivores (e.g., fishers [*M. pennant*], gray foxes [*Urocyon cinereoargenteus*]) are more abundant (Slauson 2003). Interactions between martens and other mesocarnivores along this high-contrast contact zone are likely more frequent than elsewhere in the range of the population where significant transitions in habitat structure are less dramatic, likely providing more of a buffer from competitive interactions. In addition, female-only occupancy declined much more than male-only and dual-gender occupancy. Female martens are ~40% smaller in body size than males and are thus likely more susceptible to predation by larger-bodied mesocarnivores than males. Further research will be necessary to confirm the value of serpentine habitats to martens, evaluate the potential influence of this contact zone, and determine the whether competitive interactions are significant factors affecting the marten population.

Martens have been shown to be very sensitive to relatively low levels of forest fragmentation, with several studies demonstrating that martens do not persist in landscapes where >30% of mature forest cover is lost (Chapin et al. 1998, Hargis et al. 1999, Potvin et al. 1999). The biggest difference between sites with stable marten occupancy versus unstable occupancy, in our study, was the size of the patch of Old Growth forest that encompassed them, with larger patches having more stable marten occupancy. Patch sizes of Old Growth in the study area have been reduced and fragmented through logging, all prior to 2000. Remaining smaller patches are typically adjacent to roads and young regenerating clearcuts. Early seral forest habitats are lower quality for martens and likely pose higher predation risks due to the presence of larger-bodied generalist mesocarnivores (e.g., bobcats [*Felis rufus*]) that typically exploit these early-seral habitats. Furthermore, small, fragmented coastal Old Growth patches can also be used by larger-bodied mesocarnivores that don't typically occur in larger patches. Indeed one the most fragmented sites occupied by a breeding female marten in 2000 was occupied by a male fisher in 2008. Thus, these smaller Old Growth patches (e.g., <50 ha) may be occasionally occupied, but they may not provide the same value to martens as the larger patches.

Contrary to our expectation, increasing road density had a positive influence on marten sample unit occupancy. However, the overall road density in the study area is generally low and not uniformly distributed throughout the study area. Furthermore, the difference in mean road density between sample units where marten occupancy was either stable versus where martens were absent in 2008 was small (0.5 km/km^2; Table 6). Road density is higher in non-serpentine sample units where the forest is more productive and where the majority of logging of Old Growth stands has occurred. Conversely in serpentine habitats, where the soils are less productive, few roads occur. The majority of sample units where martens were not detected in 2008 occurred in serpentine habitats. Thus, it is likely that road density is representing another unmeasured factor (e.g., site productivity) rather than providing martens any ecological benefit, a conclusion shared by Carroll et al. (1999) who also demonstrated a positive relationship between fisher occurrence and road density.

The hair snare design performed poorly at capturing quality hair samples. This is likely due to the combination of snare arrangement and that bait could be removed with minimal contact with the snare. In contrast to these results, we have used a winter hair snare design with the same type of snares deployed instead on the sides of trees. When martens visited these winter snare stations, hair was typically captured on 3-5 brushes and 80% of samples had quality DNA allowing for individual identification (Slauson unpubl. data). The difference between the winter snares is that the bait is nailed to the tree and is typically frozen, causing the martens to both remain longer near the snares and to move against the snares with more force as they try to remove the bait. To improve the summer design, the arrangement of the brushes should be changed and moved closer to the bait. The bait should also be wired into the base of the track plate enclosure to allow for more time and force for martens to contact the gun brushes. These two changes should increase the hair capture success and improve the quantity of hairs captured. However, summer hair capture success and sample quality may not approach that of winter simply because martens have their thinnest coat during summer and thickest during the winter.

Multi-state occupancy estimation appears to be a valid approach to estimate population size, considering the sampling design used. It should be interpreted as a minimum estimate for several reasons. First, we only used the sample units surveyed during the two seasons, 2000-01 and 2008. There are 8 additional sample units that were surveyed in only 1 time period and not the other. Furthermore, the sampling grid does not saturate all the habitat that is potentially occupied by the population, due both to the dendritic nature of the distribution of the habitat and the new detection locations far outside the original grid. Thus, a more realistic population estimate would be higher, perhaps even double the multi-state estimates; 60 martens in 2000-01 and 40 in 2008. Even with the shortcomings of these estimates, it is quite clear that this population is small and likely contains <100 individuals.

To improve the accuracy of any future population estimate, several steps should be taken. First, all potentially suitable habitat should be accurately mapped. Second the original sampling grid should be extended to cover more of the area of suitable habitat and densified to 1-km spacing to ensure the sampling effort is capable of detecting the majority of individuals in the majority of the suitable habitat available. Third, if DNA fingerprinting is to be used, the aforementioned modifications to the summer hair snare devices must be made.

MANAGEMENT IMPLICATIONS

The causes of the decline are unknown at this time. We cannot determine whether it is part of a natural population fluctuation or whether it is related partially or entirely due to human-caused factors. Given that the most optimistic population estimate is <100 individuals in 2008, conservation actions to benefit this remnant population are needed immediately. Specifically, a population research and monitoring program should be put into place to monitor the population to specifically determine whether there is a declining trend in the population or whether the population will rebound. If the cause(s) for decline are identified, management actions can be taken to address any identified threats.

Recent genetic findings suggest that martens in coastal Oregon are more closely related to *M. a. humboldtensis* than *M. a. caurina* in the Cascades of Oregon and that they should be reclassified within the Humboldt subspecies (Slauson et al. 2008b, N. Dawson unpubl. data). While efforts may be necessary in the short term to take action to prevent further decline of the Humboldt marten population in northwestern California, attention must also be given to reconnecting coastal California and Oregon populations to restore the population connectivity that previously existed. Thus the development of a conservation strategy should focus both on providing the immediate information needed to inform conservation actions for stabilizing the Northwestern California Humboldt marten population and determine the actions necessary to restore population connectivity between coastal California and coastal Oregon marten populations
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ACKNOWLDEGEMENTS

We wish to thank our field assistants Naomi Klass, Greg Lohse, Sheryn Olson, Lauren Perufo, and Noel Soucy. We would also like to thank Mark Lancaster and Scott Osborne and California Department of Fish and Game for field assistance and use of a vehicle. Lowell Diller, Keith Hamm, and the Green Diamond Resource Company provided assistance and access to company lands. Sandy Bar Ranch provided assistance with housing for field assistants. Brenda Devlin, Kary Schlick, and LeRoy Cyr and the Six Rivers National Forest provided funding, logistical assistance, and use of a vehicle. Region 5 of the U.S. Forest Service and the Sensitive Species program provided funding as did Robin Hamlin and the Arcata Office of the U. S. Fish and Wildlife Service. Finally we thank a number of individuals involved with the fire suppression efforts in association with the Blue II fire for fire safety training, use of safety equipment, site escorts, and logistical support for our project during the fire.

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Table 1. Definitions and abbreviations for variables measured at the home range scale (1-km radius) for each sample unit in the sampling grid during a study of American martens in coastal northwestern California, USA, 2000–2001.

Variable	Abbreviation
%Landscape Old Growth[a]	OG_Pland
% Landscape Old Growth & Late mature[a]	OGLM_Pland
% Landscape Serpentine Habitat[a]	SERP_Pland
% Landscape Serpentine Habitat & Old Growth[a]	SERP_OG_Pland
% Landscape Young Growth[a]	YNG_Pland
Number of Habitat Patches of Young Growth[a]	YNG_NP
Road Density[b]	Road_Dens

[a] Measured from the vegetation coverage produced by the Ecology Program of the Six Rivers National Forest.

[b] Measured from the transportation layer provided by the Six Rivers National Forest.

Table 2. Definition of the multi-state detection probability structure for the 4 detection models evaluated. Models with "=Gender" assume the probability of detection is the same for both genders and "!=Gender" assume the detection probabilities differ by gender.

True State	**Prob. of true state**	**Observed state**	**Probability of observed state given true state for a single visit**			
			***p*(full)**	**Visit # dependence *p*(visit #)** $\text{logit}(p_v) = a + b \cdot v$	***p*(=Gender)**	***p*(!=Gender)**
Absence	ψ_A	No detections	1	1	1	1
		Male	0	0	0	0
		Female	0	0	0	0
		Both genders	0	0	0	0
Male Only	ψ_M	No detections	$p_{M,A}$	$1 - p_v$	$1 - p$	$1 - p_M$
		Male	$p_{M,M}$	p_v	p	p_M
		Female	0	0	0	0
		Both genders	0	0	0	0
Female Only	ψ_F	No detections	$p_{F,A}$	$1 - p_v$	$1 - p$	$1 - p_F$
		Male	0	0	0	0
		Female	$p_{F,F}$	p_v	p	p_F
		Both genders	0	0	0	0
Both Genders	ψ_{MF}	No detections	$p_{MF,A}$	$(1 - p_v)^2$	$(1 - p)^2$	$(1 - p_M)(1 - p_F)$
		Male	$p_{MF,M}$	$p_v(1 - p_v)$	$p(1 - p)$	$p_M(1 - p_F)$
		Female	$p_{MF,F}$	$p_v(1 - p_v)$	$p(1 - p)$	$p_F(1 - p_M)$
		Both genders	$p_{MF,MF}$	p_v^2	p^2	$p_M p_F$

Table 3. Species detected using sooted track plates, on the Six Rivers National Forest and Green Diamond Resource Company lands, from June to August, 2008.

Species	Sample Units (n = 45)	# Visits*
Carnivores		
Marten	17(40%)	44
Male	12 (27%)	26
Female	9 (20%)	18
Fisher	5 (11%)	12
Male	2 (4%)	4
Female	2 (4%)	8
Gray Fox	2 (4%)	9
Western spotted skunk	2 (4%)	2
Ringtail	1 (2%)	1
American black bear	14 (31%)	20
Long/Short-tailed weasel	3 (6%)	8
Rodents		
Northern flying squirrel	5 (11%)	9
Douglas squirrel	3 (7%)	3
Chipmunk Sp.	27 (60%)	99
Mice Sp.	44 (98%)	267
Other		
Lizard Sp.	1 (2%)	1
Unknown	2 (4%)	2

* # Visits indicates the total number of visits by each species to track plate stations across all sample units.

Table 4. Candidate occupancy models for American martens studied in coastal northwestern California, USA, 2000–2001 and 2008, ranked according to ΔAIC_c value. Dashed line indicates end of the 95% confidence set of models.

	Model Parameters				Model Ranking		
Model #	ψ	*p*	ε	γ	ΔAIC_c	*wi*[a]	K[b]
1	Constant	Visit Group	Constant	Constant	0.00	0.17	7
2	Constant	Visit Group	OG _Pland	Constant	0.39	0.14	8
3	Constant	Visit Group	Road_Dens	Constant	0.56	0.13	8
4	Constant	Visit Group	OG _Pland Road_Dens	Constant	1.02	0.10	9
5	Constant	Visit Group	YNG_Pland Road_Dens	Constant	1.08	0.10	9
6	Constant	Visit Group	YNG_NP	Constant	1.65	0.08	8
7	Constant	Visit Group	OG__Pland	OG__Pland	2.00	0.06	9
8	Constant	Visit Group	OG_SRP _Pland	Constant	2.60	0.05	8
9	Constant	Visit Group	OGLM_SRP_Pland	Constant	2.60	0.05	8
10	Constant	Visit Group	OGLM _Pland	Constant	2.60	0.05	8
11	Constant	Visit Group	YNG _Pland	Constant	2.61	0.05	8
— — —	— — —	— — —	— — —	— — —	— — —	— — —	— — —
12	Constant	Visit Group	OGLM_Pland SRP_Pland	Constant	5.31	0.01	9
13	Constant	Wk 1 v Wk 2	Constant	Constant	8.90	0.00	5
14	Constant	Constant	Constant	Constant	10.90	0.00	4
15	Constant	Year	Constant	Constant	11.80	0.00	5
16	Constant	Visit-Specific	Constant	Constant	20.19	0.00	11
17	Constant	Visit-Specific By Year	Constant	Constant	34.83	0.00	19

[a] *wi* = Akaike weight, corrected for small sample sizes.
[b] K = number of parameters in a model.

Table 5. Normalized importance weights for stand scale variables from occupancy models for American martens studied in coastal northwestern California, USA, 2000–2001 and 2008.

Road Density	0.209
% Landscape in Old Growth	0.192
# Young Growth Patches	0.141
% Landscape in Young Growth	0.137
% Landscape in Old Growth and Serpentine	0.088
% Landscape in Old Growth and Late Mature	0.088
% Landscape in Serpentine	0.022

Table 6. Means (SEs) for the 7 habitat variables used in occupancy modeling for American martens in coastal northwestern California.

Observed Occupancy Status	Habitat Variables						
	OG_Pland	OGLM_Pland	SRP_Pland	OG_SRP_Pland	YNG_PLand	YNG_NP	Road_Dens
Stable (n = 11)	31.0% (51)	49.7% (48)	33.3% (146)	52.0% (104)	22.7% (42)	6.1 (9)	1.3 (3)
Extinct (n = 12)	19.1% (70)	45.6% (89)	36.5% (145)	52.0% (114)	25.4% (83)	5.2 (10)	0.9 (3)
Colonized (n = 4)	16.0% (14.9)	28.4% (22)	56.7% (77)	62.0% (57)	29.9% (30)	5.8 (4)	1.4 (2)
Unoccupied (n = 5)	34.0% (43)	63.3% (44)	25.35% (75)	45.0% (53)	16.6% (35)	5.2 (11)	0.9 (2)

Table 7. Candidate multi-state occupancy models for American martens studied in coastal northwestern California, USA, 2000–2001 ranked according to ΔAIC_c value.

		Model Parameters		Model Ranking			Estimates for $(\hat{\psi}_M + \hat{\psi}_F + 2\hat{\psi}_{MF})$ (SE)	
Season	Model #	ψ	p	ΔAICc	wi[a]	K[b]	Individual Model	Model Avg.
2000-01	1	Constant	Gender =	0.00	0.75	4	1.04 (0.13)	1.05 (0.14)
	2	Constant	Gender ≠	2.73	0.21	5	1.32 (0.19)	
	3	Constant	Full	6.50	0.01	8	1.77 (0.03)	
	4	Constant	Visit Group	6.94	0.01	5	1.68 (0.02)	
2008	1	Constant	Visit Group	0.00	0.50	5	0.69 (0.17)	0.68 (0.16)
	2	Constant	Gender =	0.39	0.40	4	0.66 (0.15)	
	3	Constant	Gender ≠	3.32	0.09	5	0.66 (0.15)	
	4	Constant	Full	8.94	0.00	8	0.69 (0.18)	

[a] wi = Akaike weight, corrected for small sample sizes.
[b] K = number of parameters in a model.

Figure 1. Track plate sample units surveyed in 2000-01 and in 2008 for American martens in coastal Northwestern California.

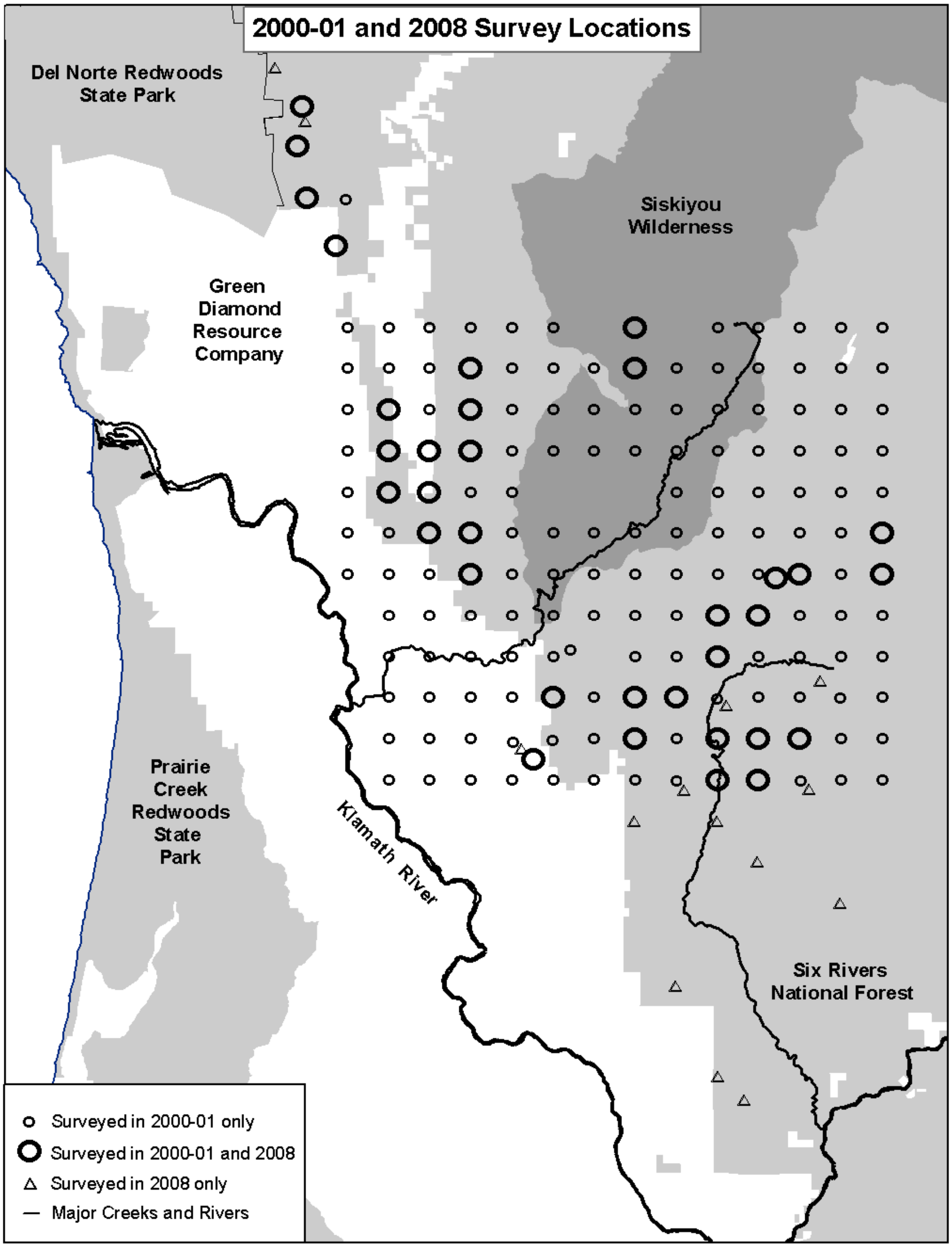

Figure 2. Track plate survey results for American martens for 2000-01 and 2008, in coastal Northwestern California.

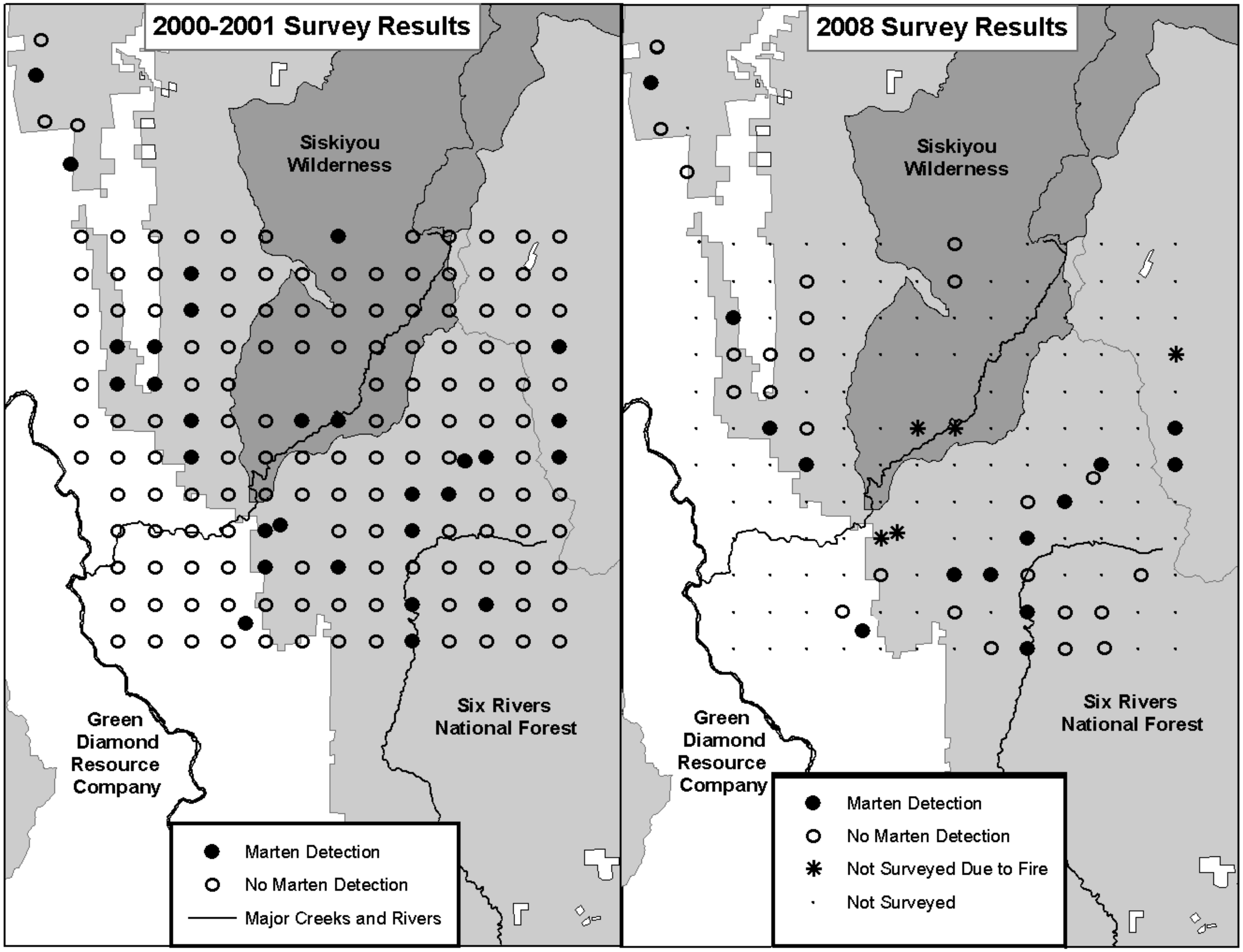

Figure 3. Location and observed detection results for the original survey grid and the 15 expansion sample units surveyed in July and August 2008.

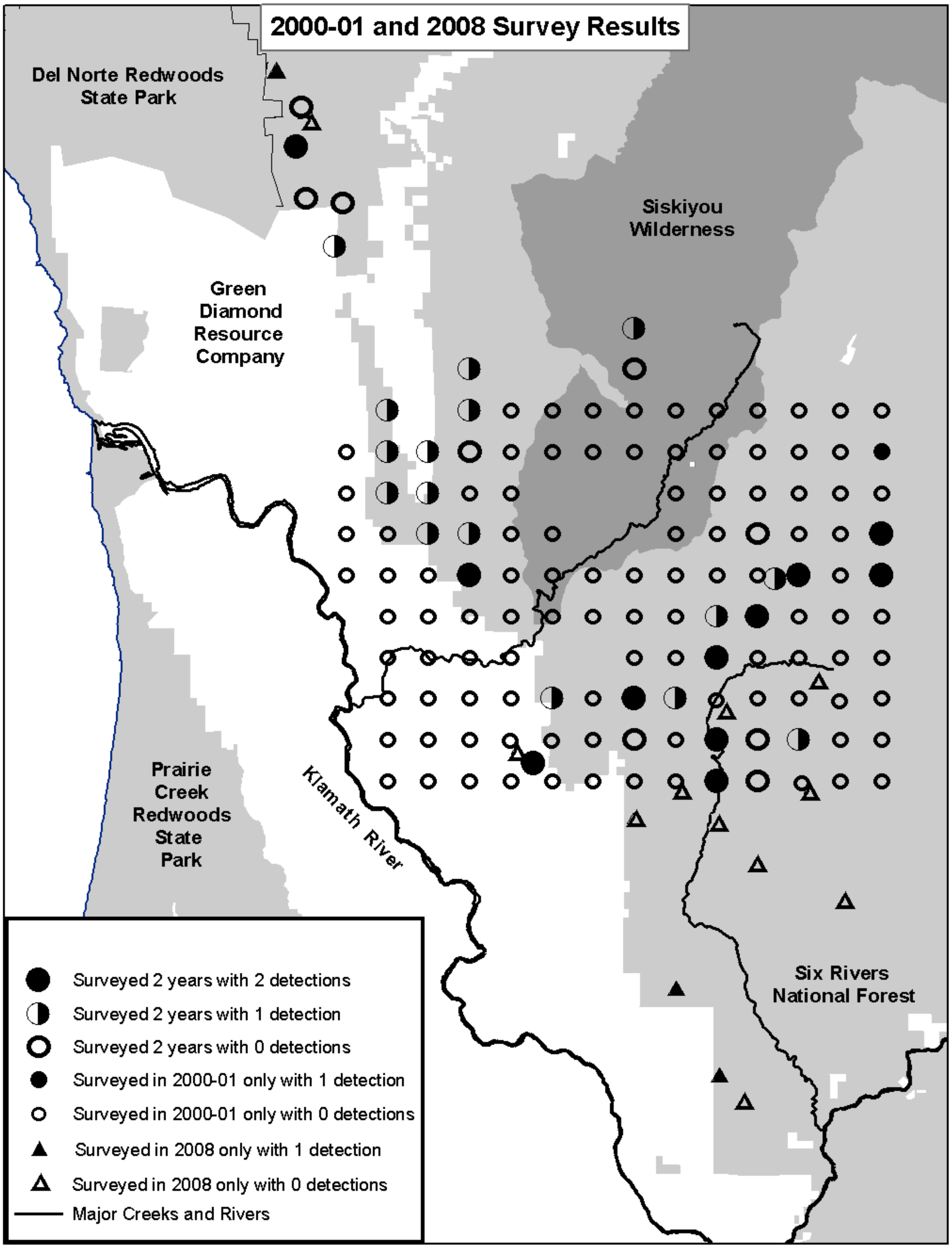

Figure 4. American marten detections from 2000-08 and the extent of the 2008 Blue II fire.