Preliminary estimate of fisher populations in California and southern Oregon

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Abstract

While historically there have been few estimates of the fisher population size in California, currently there are a number of fisher density estimates which are generally well distributed throughout the historic range of fisher. We used these existing density estimates and two separate methods to estimate the total fisher population size in California. Our deterministic expert method estimated 3,079 fisher in the northern California population and 598 fisher in the southern Sierra Nevada population for a total of 3,677 fisher within California. This method also estimated 4,018 fisher in the combined northern California and southern Oregon population and 598 in the southern Sierra Nevada population for a total of 4,616 fishers within southern Oregon and California. Our linear regression method estimated 3,199 fisher +/- 815 within the northern California population and 548 fisher +/- 181 within the southern Sierra Nevada population for a total of 3,747 fisher within California. Our two separate preliminary estimates of the fisher populations in California compared favorably, indicating any potential limitations with our model based estimate may be relatively minor at the population scale.

Introduction

Historically, there have been few estimates of fisher population size in California. These estimates range from a few hundred total in the State (Grinnell et al. 1937) to 200-500 just in the southern Sierra Nevada population (Lamberson et al. 2000). No other published population estimates exist for fisher in either the northern California or southern Sierra Nevada populations in California. Unfortunately, the two existing estimates were not based on adequate empirical evidence and suffer from a lack of density estimates from which to extrapolate to overall population numbers.

Currently, a number of fisher researchers in California have developed density estimates for their study areas. Others have presented sufficient data to develop a density estimate for their respective study areas. These areas and their associated density estimates can be used to develop a scientifically based population estimate. By using a deterministic expert method which uses the best available empirical evidence of fisher densities combined with appropriate habitat and area maps, population estimates for fishers both in the northern California (including its extension into southern Oregon south of the Rogue River and west of Interstate Highway 5) and southern Sierra Nevada populations can be developed.

In addition, existing landscape level models describing fisher presence or abundance are based primarily on vegetation structure and composition (Carroll et al. 1999, Carroll 2005, Lamberson 2000). Specifically, predictive variables have focused on previous research describing fisher denning and resting habitats (Buck et al. 1983, Rosenburg and Raphael 1986, Slauson and Zielinski 2003, Criss and Kerns 1990, Self and Kerns 1995), even though abiotic variables like elevation and precipitation have been significant at predicting fisher presence (Carroll et al. 1999, Campbell 2004). Although, few studies have described fisher foraging habitats in California, fisher have been found to opportunistically forage on a wide variety of small and medium sized mammals, birds, insects and reptiles (Powell et al. 1997, Zielinski et al. 1999). As foraging generalists, fisher likely take advantage of the wide ecological diversity contained within the State of California.

Some researchers have hypothesized that the distribution of wildlife species, species richness and overall biological diversity are directly related to primary productivity and that species density may be described better by primary productivity of landscapes (Currie 1991, Hansen et al. 1995, Hansen and Rotella 1999). In addition, distribution of some species and population sizes may also be influenced by ecosystem productivity (Waide et al. 1999). Since fisher forage on a wide variety of prey, fisher abundance may be better described by predictive variables which describe net primary productivity of the landscape such as mean annual precipitation, mean annual temperature, annual potential evapotranspiration, and solar radiation (Currie 1991, Hansen et al. 1995). In fact, predictive variables of net primary productivity like mean annual rainfall have been significant predictors of fisher presence in California (Campbell 2004, Carroll et al. 1999). Based on the hypothesis that, at the landscape scale, ecosystem productivity and fisher prey abundance may estimate fisher abundance, we also developed a landscape level model to estimate the number of fisher in California.

Methods

From the literature and personal communications with fisher researchers, we compiled or developed density estimates for eleven fisher study areas located across California (Table 1, Figure 1). These eleven study areas range from the California coast near Eureka, north and east to the California/Oregon border near Yreka, and to the southern Sierra Nevada south of Yosemite National Park. Where available, density estimates were taken directly from published or gray literature. In other cases, estimates were developed in conjunction with the respective researchers. However, the density estimate for the Big Bar Study Area was over twice as high as any of the other study area estimates. As it is unclear from the source publication how the estimate was developed, this estimate was excluded from all analyses. Table 1 provides details regarding the density estimate for each study area.

Following the compilation or development of the density estimates, we used two separate methods to expand the density of fisher associated with each fisher study area to allow estimation of native fisher densities across all currently occupied areas of California and southern Oregon (excluding the reintroduced fisher population in Oregon). One method was a deterministic expert based approach and the other was an analytic model based approach to arrive at two separate population estimates.

Deterministic expert estimate method

The deterministic expert approach was used to develop a habitat map responsive to the study areas with density estimates by incorporating information from FRAP (2003), rainfall nomographs, elevation, and ecological zones of California (USDA 1997). Foresters and biologists familiar with northern California and with fishers and their habitat stratified a base map of California into sub-areas of potential fisher habitat around each of the study areas. Potential habitat within each density estimate area was defined as the area within the Grinnell et al. (1937) fisher range boundary currently occupied by fisher (USDI 2008) and supporting conifer or mixed-conifer/hardwood forest below 5000 ft. elevation in northern California, increasing on a sliding scale to an 8000 ft. ceiling in the southern Sierra Nevada. By excluding high elevation areas, we effectively removed the land supporting a deep winter snow pack, little used by fisher in California and elsewhere (Krohn et al. 1997). This method also excluded areas of low quality forest, open valleys and grass lands, agricultural lands, urban areas and extensive shrub lands.
The resulting landscape which fisher potentially use within the known range in California is described as fisher core habitat in Figure 1.

By defining the boundaries of potential fisher core habitat within each density estimate area as described above, we were able to assign the density estimates to the higher quality habitat within each density estimate area (Figure 1). Thus, areas not likely to support resident fisher because of inadequate habitat due to elevation constraints (i.e. too much winter snow) which may also limit vegetation composition were removed from density calculations for each area, generally avoiding the problem of assigning fisher density estimates to areas of low quality fisher habitat.

Model estimate method

A series of *a priori* hypotheses were made to test the current understanding of fisher biology and explore possible new associations with fisher density. We intentionally limited the number of independent variables (i.e. hypotheses) that were examined, due to our limited sample size (n=10). In all hypotheses tested, the dependent variable was the total density of fisher found within each previously reported study area, described as the number of fisher per $100km^2$ (Table 1). A geographic information system (GIS) was used to project the independent variables used to describe each of the four hypotheses. The GIS coverages chosen to test the four hypotheses needed to both accurately describe the independent variable and cover the entire range of fisher in California. These requirements limited the number of appropriate coverages. The four hypotheses tested were:

(1) Old-growth and late-seral habitats functioning as denning and resting sites provides an adequate estimate of fisher density. Old growth and late-seral habitat mapping was described by 22 classes of forest vegetation from potential forest (value 1) through large multistory conifer (value 22) plus water, barren lands, etc. at 25 meter resolution. Source data was Interagency Vegetation Mapping Project (IVMP) coverages for quadratic mean diameter (QMD), stand structure, and conifer vegetation from Landsat TM ca. 1996. Mapped by the Regional Interagency Effectiveness Monitoring Program, NW Forest Plan, R6/PNW in 2005 (Moeur et al., in press). In this effort we used all types with average diameter >= 10 inches excluding > 80% deciduous forests.

(2) Habitat suitable for territorial northern spotted owls provides an adequate estimate of fisher density. Territorial northern spotted owl habitat is from version 1.0 of northern spotted owl habitat suitability for the California Klamath physiographic province. It was modeled using BioMapper (v3.1) software (Hirzel 2004). BioMapper is a recently developed software package that contains GIS and statistical tools designed to build habitat suitability models and maps using species-presence-only data. The model performs an ecological niche factor analysis that compares ecological conditions that correspond with species presence to conditions across the entire area being analyzed. The suitability statistic is based on the similarity of the biotic and abiotic characteristics of a habitat-capable map unit (pixel) to the characteristics of sites inhabited by territorial owls. Habitat suitability ranges from 0-100. A value close to zero signifies that an individual map unit has little in common with the conditions found where territorial owls are present, and those with values close to 100 have much in common with sites having territorial owl presence. Our use in California, included all habitat suitability values greater than 40. This value was used since it was determined to encompass 90% of the known owls in the California Klamath Province (Lint in press).

(3) Primary productivity of the landscape in which fisher forage provides an adequate estimate of fisher density. Primary productivity was described by latitude, longitude, and weighted by area of mean annual rainfall. We used a statewide coverage of public land surveys (PLS) and rainfall nomograph polygons to develop this weighting.

(4) Broad scale vegetation composition of the landscape in which fisher forage provides an adequate estimate of fisher density. We used vegetation composition from Landsat TM satellite imagery at 57-meter pixel resolution that describes the amount of conifer, hardwood, shrub, and non forest habitats in a statewide seamless coverage (FRAP 2003).

There are a number of independent variables that may better explain variation in fisher densities that were not used in this model estimate method. Mean annual temperature, annual potential evapotranspiration (PET), solar radiation, and net primary productivity (NPP) have been significant in predicting wildlife species richness, diversity and, for some species, population sizes. Unfortunately, time constraints and potential availability of GIS coverages for the entire range of fisher in California excluded these variables from consideration.

We also reviewed each of the 10 existing fisher density studies used in the deterministic expert approach in developing the model estimate method (Figure 1). All study areas were considered suitable, except for the Pacific Lumber Company density estimate. Due to that study's reliance on a spatial estimate of home range applied to areas where fisher were detected with non-randomly selected camera stations, we believe assumptions made in the study's density estimate conflict with assumptions made in the model estimate method. Accordingly, only nine study areas were used for this model estimate.

Results

Deterministic expert estimate of fisher populations

Using the deterministic approach resulted in the designation of 10 separate density estimate areas, 8 in the northern population area and 2 in the southern population area. Except within the southern population, each density estimate area is associated with one or more fisher study areas with density estimates (Figure 1). The southern Sierra Nevada fisher population was divided into two density estimate areas to allow a lower density estimate to be used for the area north of the Kings River. This was because detection rates are lower in this portion of the occupied southern area (Truex pers. comm. 2007). The Zielinski et al. (2004) density estimate was reduced by one-third for the area north of the Kings River.

The total acres of potential fisher habitat for the two occupied areas equal 9,630,326 acres (Table 2). The percent of each sub-area comprised of potential fisher habitat ranged from 44% to 90%, generally decreasing from the coast to inland and from north to south. Within California, potential fisher habitat comprises approximately 70% of the total area within the range boundary of Grinnell et al. 1937. Of the total fisher potential habitat within the range boundary including the portion in Oregon, approximately 47% percent is currently occupied. A density estimate for each sub-area was calculated and a total fisher population estimated, resulting in 4,616 fishers within southern Oregon and California with 4,018 in the northern population and 598 in the southern population. Within just the California portion of the northern California/southern Oregon, the population was estimated at 3,079 fisher. Combining this value with the 598 fisher estimated to exist in the southern Sierra Nevada population gives a total of 3,677 fisher within the State of California (Table 2).

Model estimate of fisher populations

A linear regression was completed between the density of fisher reported in nine previous studies and the four *a priori* hypothesis containing 10 different independent variables (Table 3). The percent of old growth and late-seral habitats (R^2=0.15, p>0.1) and the habitat suitable for territorial northern spotted owls (R^2=0.21, p>0.1) did not predict the density of fisher. Using all 9 study areas the mean latitude (R^2=0.004, p>0.1) and mean longitude (R^2=0.039, p>0.1) did not predict the density of fisher. However, due to the large differences in latitude and longitude between the northern California study areas with the southern Sierra Nevada study area, when the southern Sierra Nevada study was excluded and only the 8 study areas in the northern California population were examined, mean latitude (R^2=0.014, p>0.1) and decreases in mean longitude (R^2=0.37, p>0.1) better described fisher density. For all 9 study areas, Increases in mean annual rainfall (R^2=0.43, p=0.07) and increases in percent conifer vegetation (R^2=0.36, p=0.09) were correlated to fisher density, but were not significant at the $p < 0.05$ level. The Pearson's correlation coefficient between mean annual rainfall and percent conifer vegetation was significant (p=0.02). Percent hardwood forest (positive relationship, R^2=0.65, p=0.01) and percent shrub vegetation (negative relationship, R^2=0.56, p=0.02) were significantly correlated to fisher density.

In developing a model to estimate the variable densities of the two fisher populations, a multi-step regression was constructed using the best independent variables. The model which correlated the best with density of fisher and created the smallest standard error was (R^2=0.73, p=0.06, SE 3.05);

$$\textit{Number of fisher / 100 km}^2 = 8.04 + 0.077*\textit{Mean Rainfall} + 0.104*\textit{Percent Hardwood Forest} - 0.342*\textit{Percent Shrub}$$

Even though mean annual rainfall and percent conifer were highly correlated, when percent conifer was entered into the model in lieu of mean annual rainfall, the correlation decreased, the significance decreased and the standard error remained the same (R^2=0.70, p=0.08, SE 3.10).

To use the model to estimate fisher within the known range of fisher and within the fisher core habitat area (Figure 2), northern California and southern Sierra Nevada fisher occupied areas were mapped into 437 and 148 unique township and range combinations, respectively. The township and range combinations were used as they approximate a landscape scale of 100km^2 frequently reported in fisher densities studies. The mean annual rainfall, percent hardwood forest, and percent shrub vegetation were calculated for each unique township and range combination. Then the fisher core habitat area boundary used in the deterministic expert approach was used in the model approach to restrict prediction of fisher density to below 5,000 feet and 8,000 feet in elevation in northern California and the southern Sierra Nevada, respectively. Using the unique landscape values within each township and range combination, the number of fisher within each township and range combination was estimated by the model and converted to a 100km^2 basis (Figure 2). The total estimated fisher population within the northern California population (not including southern Oregon) was 3,199 fisher +/- 815 (SE) and within the southern Sierra Nevada population was 548 fisher +/- 181 (SE).

Discussion

Our two separate preliminary estimates of the fisher population size using a deterministic expert method and regression model based approach compared favorably. For the southern Sierra Nevada fisher population the deterministic expert method estimated 598 fisher and regression model estimated 548 fisher +/- 181 (SE). Since the deterministic expert method fell well within the standard error estimate of the model, we believe the two separate methods compared favorably. As our preliminary estimates of 548 to 598 fisher in the southern Sierra Nevada are based on an existing density estimate, we believe our results suggest the southern Sierra Nevada fisher population is near the upper extent of previous estimates of 200 to 500 fisher by Lamberson et al. 2000. Within the northern California population, the deterministic expert method estimated 3,079 fisher and regression model estimated 3,199 fisher +/- 815 (SE). Again, the two separate methods compared favorably suggesting that mean annual rainfall and the amount of hardwood and shrub habitats, variables found important in predicting fisher density, are not only found in density study areas, but also fairly represent climate and habitat conditions found in other portions of the current and historic fisher range in California.

The development of our landscape model to estimate the number of fisher using a regression based model has several potential limitations. Due to our relative small sample size (n=9) we did not test our model against any "hold back" data or other studies to validate our estimates. We would encourage the use of other study areas, if they exist, to attempt to validate our estimates. One of the studies used to develop our model is on-going, Collins-Baldy/Mt. Ashland study, and the number of individual fisher per 100 km^2 into the future is unknown, which could influence results of our model estimate. In addition, approximately half of the density estimates were developed using only the minimum number of fisher alive for each study area, which generally under represents the actual fisher density. We consider this model estimate of fisher in California as preliminary, since time limited our ability to acquire several additional landscape level GIS coverages, which may be significant in describing fisher densities in California. While our results demonstrate some linear relationships between independent variables and fisher densities, non-linear relationships also likely exist but were not explored in this study. Also, we did not use Akaike Information Criterion (AIC) values to determine the best model, which may have improved our study. While our preliminary model estimate of fisher populations in California may have some potential limitations, and any regression based estimate should be viewed cautiously, the favorable comparison to our original deterministic expert estimate suggests any limitations may be relatively minor at the population scale.

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Figure 1. Eleven fisher density estimate study areas within California. 10 density study areas identified in hatched yellow. Density estimate areas surrounding study areas limited to areas currently believed to be occupied by fisher (USDI 2008)

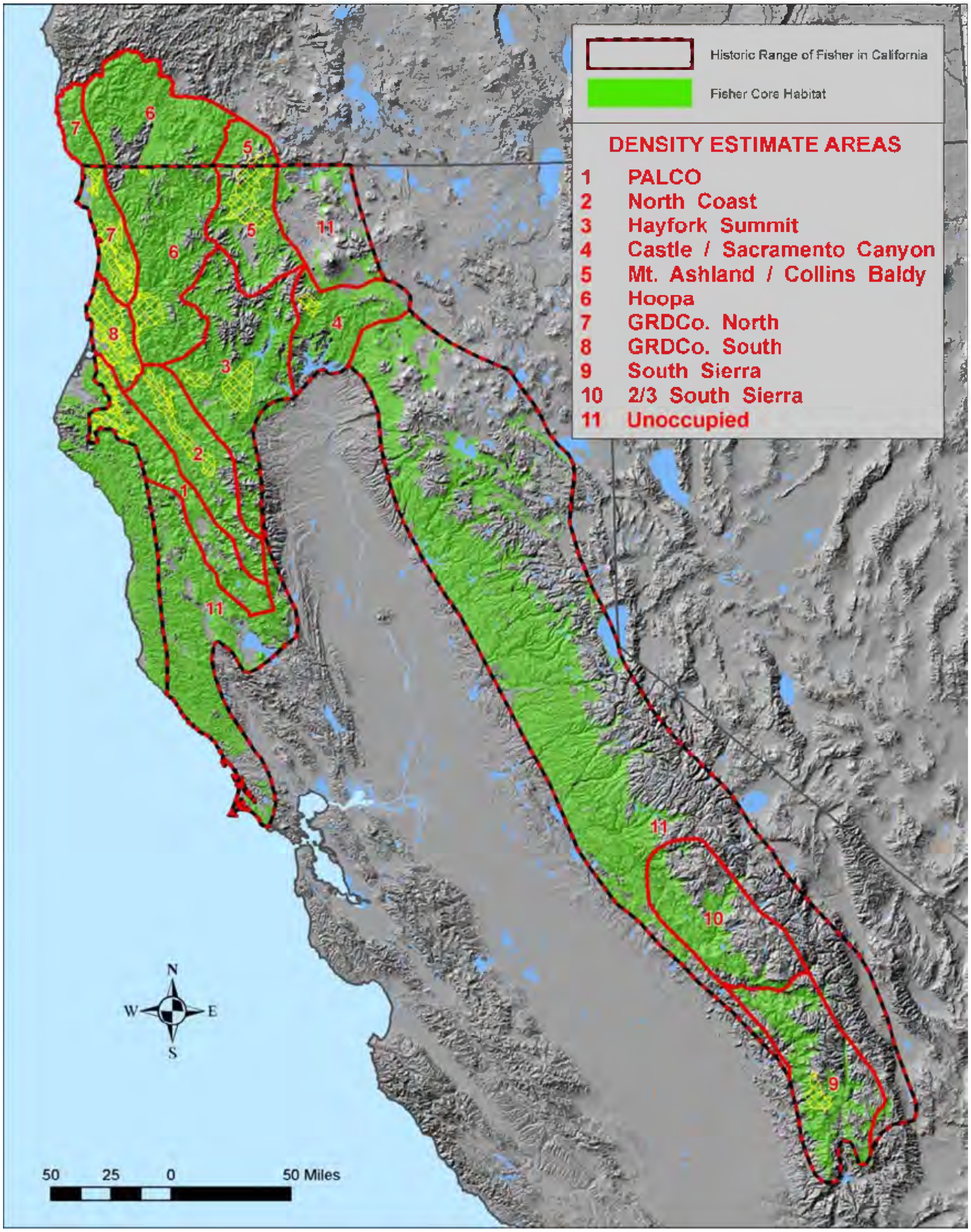

Figure 2 Model based estimate of fisher populations within California

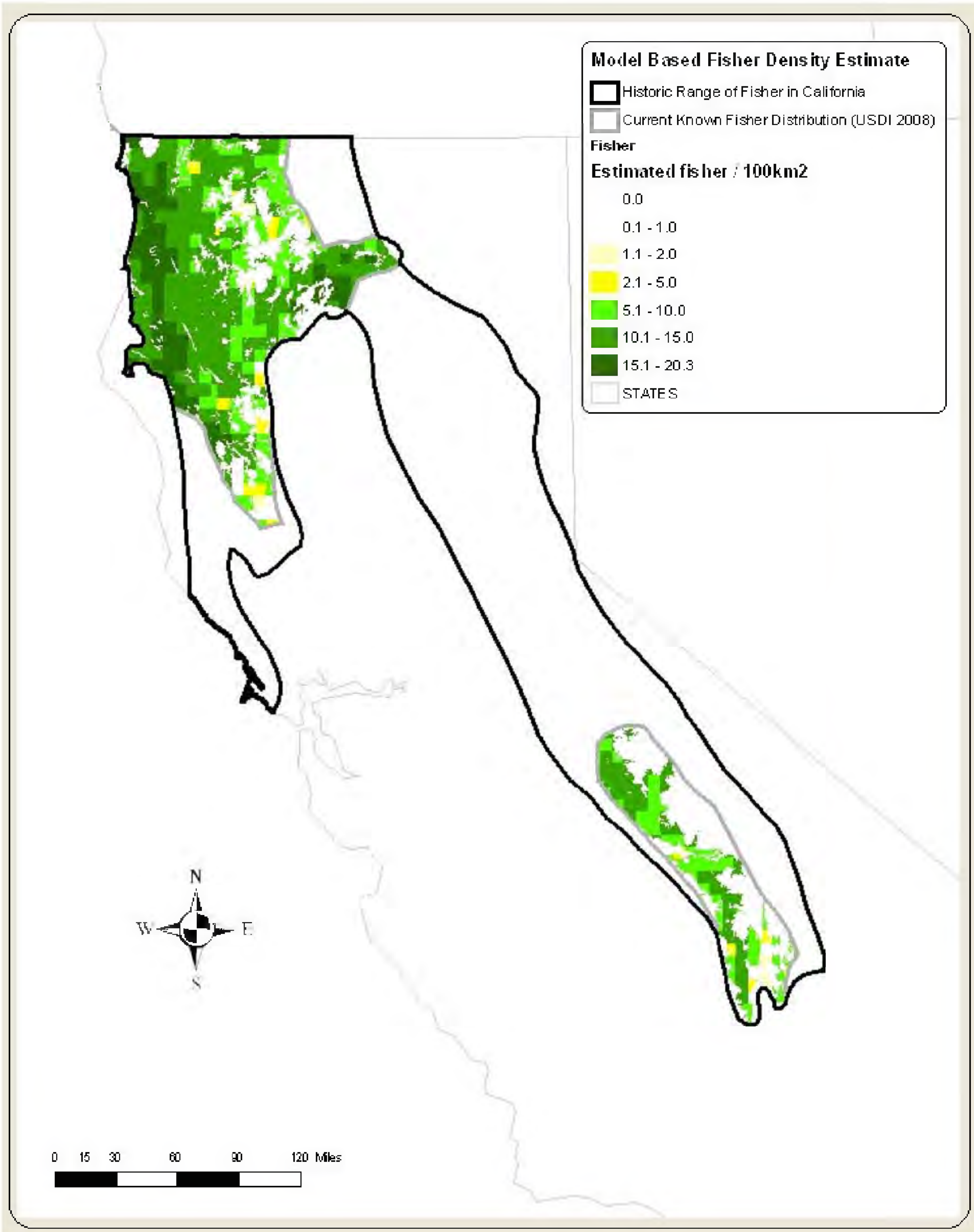

Table 1. Fisher Density Estimates from Study Areas in California (including the extension into southern Oregon)

Study Area (years of data collection)	Density Estimate (# fisher/100 km^2)	Size of Area (km^2)	Source	Notes
North Coast (1993-1997)	8.0	400	Zielinski et al. 2004 Truex et al 1998	Based on trapping results, assumed 1:0.5 female:male ratio to expand from female only estimate to total density estimate
Hoopa Square (2005)	14.7	400	Higley, pers. comm. 2008	Minimum number alive[2] based on using 12.5 km^2 effective area for each trap and expanding to entire area of Hoopa reservation
Green Diamond North (2002-2003)	19.8	100	L. Diller, pers. comm. 2008	Used capture/re-capture method to estimate density
Green Diamond South (2002-2003)	15.6	100	Diller, pers. comm. 2008	Used capture/re-capture method to estimate density
PALCO (2000-2005)	4.8	850	S. Chinnici, pers, comm. 2008	Estimated density using camera station inventory to establish occupancy and home range estimates from Buck et al. 1983 and Zielinski et al. 2004 to estimate density
Big Bar (1977-1979)	44.0	150	Buck et al. 1983	As described in Buck et al (1983), density estimated by using home range information expanded to entire study area
Collins Baldy, Mt. Ashland and Deadwood (2005-2006)	5.7	470	Farber pers. comm. 2008	Minimum number alive based on total individuals captured. Study area defined by Zielinski and Kucera (1995) protocol 4 mile^2 trapping grid
Castle Creek (1991-1994)	6.3	47	Self and Kerns 1995	Minimum number alive based on total individuals captured. Effective trapping area = 5.2 km^2 per trap site. Data averaged over 3 trapping periods
Sacramento Canyon (2006 & 2008)	12.9	44	Reno et al. 2008	Minimum number alive based on total individuals captured. Effective trapping area = 5.2 km^2 per trap site.[3] Data averaged over 2 trapping periods
Hayfork Summit (2006-2008)	14.1	127	Reno et al. 2008, Self pers. comm. 2008	Minimum number alive based on total individuals captured. Effective trapping area = 5.2 km^2 per trap site. Data averaged over 3 trapping periods
Southern Sierra (1994-1996)	12.0	280	Zielinski et al. 2004 Truex et al 1998	Based on trapping results, assumed 1:0.5 female:male ratio to expand from female only to total density estimate

[2] Minimum number alive method is likely an underestimate of the actual number of fisher in a study area. This method counts only the number of individual fishers detected and does not account for non-detected individuals.
[3] 5.2 km^2 is the average effective area trapped using the Zielinski and Kucera(1995) meso-carnivore detection grid with 2 detection devices per 4 square mile area.

Table 2. Acres of Fisher Habitat by Density Estimate Area, and Population Estimates

Density Estimate Area (Map Number, Figure 1)	Total Acres	Acres of Potential Fisher Habitat[4]	% of Total Acres That are Potential Fisher Habitat	Density Estimate (fisher/100 km^2)	Fisher Population Estimate
GRDCo North (7)	730,372	660,310	90.4	19.8	529
GRDCo South (8)	404,982	364,834	90.1	15.6	230
PALCO (1)	947,230	816,608	86.2	4.8	159
Hoopa (6)	3,074,511	2,693,648	87.6	14.7	1603
North Coast (2)	1,025,558	860,137	83.9	8.0	279
Mt. Ashland/Collins Baldy (5)	1,109,448	766,301	69.1	5.7	177
Hayfork Summit[5] (3)	1,989,932	1,420,613	71.4	14.1	811
Castle/Sac. Canyon[6] (4)	903,918	592,417	65.5	9.6	230
2/3rds South Sierra (10)	1,522,089	671,442	44.1	8.0	217
South Sierra (9)	1,624,240	784,016	48.3	12.0	381
Unoccupied Area (11)	14,859,207	6,791,195	45.7	N/A	N/A
Totals of Occupied Areas	13,332,280	9,630,326	72.2	--	4616

California Totals	11,495,988	8,019,783	69.8	--	3677
Oregon Totals	1836292	1610543	87.7	--	939

Acreage Totals within Historic Range and Oregon	28,191,487	16,421,521	58.2	--	--

[4] Potential fisher habitat is defined here as area within the Grinnell et al (1938) fisher range boundary supporting conifer and mixed conifer forest below 5,000 ft elevation in the north, increasing with a sliding scale to an 8,000 ft. ceiling in the south.
[5] The Big Bar fisher density estimate was not used, as it was an obvious outlier from all other density estimates.
[6] Castle Creek and Sacramento Canyon Density estimates were averaged for this area.

Table 3 Regression of predictive variables

Hypothesis	Independent Variable	n	R^2	Coefficient (+ or -)	Significance
Old-growth & late-seral conifer habitats	% LSOG class (Moeur et al. in press)	8	0.148	+	p > 0.1
Habitat suitable for territorial northern spotted owls	% habitat STOC code >= 40, Biomapper model (Lint in press)	8	0.210	+	p > 0.1
Primary Productivity	Latitude	9	0.004	+	p > 0.1
	Longitude	9	0.039	+	p > 0.1
	Latitude + Longitude	9	0.001	+	p > 0.1
	Mean Annual Rainfall	9	0.434	+	p = 0.07
Vegetation Composition	% Conifer	9	0.356	+	p = 0.09
	% Hardwood forest	9	0.648	+	p = 0.01
	% Shrub	9	0.559	-	p = 0.02
	% Herbaceous	9	0.023	-	p > 0.1
Landscape Level Model	Mean Annual Rainfall + % Hardwood forest - % Shrub	9	0.732		p = 0.06