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Using occupancy and population models to assess habitat conservation opportunities for an isolated carnivore population

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ABSTRACT

An isolated population of the fisher (*Martes pennanti*) in the southern Sierra Nevada, California, is threatened by small size and habitat alteration from wildfires, fuels management, and other factors. We assessed the population's status and conservation options for its habitat using a spatially explicit population model coupled with a fisher probability of occurrence model. The fisher occurrence model was selected from a family of generalized additive models (GAM) generated using numerous environmental variables and fisher detection–nondetection data collected at 228 survey arrays sampled repeatedly during 2002–2006. The selected GAM accounted for 69% of the Akaike weight using total above-ground biomass of trees, latitude-adjusted elevation, and annual precipitation averaged over a 5 km^2 moving window. We estimated equilibrium population sizes (or carrying capacities) within currently occupied areas, and identified likely population source, sink, and expansion areas, by simulating population processes for 20 years using different demographic rates, dispersal distances, and territory sizes. The population model assumed that demographic parameters of fishers scale in proportion to habitat quality as indexed by the calculated probability of fisher occurrence. Based on the most defensible range of parameter values, we estimate fisher carrying capacity at ~125–250 adults in currently occupied areas. Population expansion into potential habitat in and north of Yosemite National Park has potential to increase population size, but this potential for expansion is predicted to be highly sensitive to mortality rates, which may be elevated in the northern portion of the occupied range by human influences, including roadkill and diseases carried by domestic cats and dogs.

1. Introduction

The fisher (*Martes pennanti*) is a large member of the weasel family associated with dense, structurally complex, low- to mid-elevation forests in North America (Powell and Zielinski, 1994; Buskirk and Zielinski, 2003; Powell et al., 2003). Remaining populations in the western US are small, disconnected from one another, and threatened by habitat modification and fragmentation (Powell and Zielinski, 1994; Aubry and Lewis, 2003; Zielinski et al., 2005). The Pacific coast population is a candidate for listing under the US Endangered Species Act (ESA), and populations in California are candidates for listing under the California ESA.

Fishers were apparently eliminated from the central and northern Sierra Nevada, California, during the 20th century due to trapping, logging, and other habitat modifications (Zielinski et al., 1995, 2005). This isolated a population in the southern Sierra Nevada, south from the western edge of Yosemite National Park to the Greenhorn Mountains and Kern Plateau (Zielinski et al., 2005). Forests in the region are experiencing increasing risks of large, stand-replacing wildfires due to previous forest management actions (e.g., fire suppression, logging; Agee and Skinner, 2005), climate change (Westerling et al., 2006), and increased ignition rates due to humans (Syphard et al., 2007). However, management actions intended to reduce fire risks (e.g., forest thinning, prescribed fire) have been highly controversial, in part because fishers tend to select the densest forests as resting habitat (Zielinski et al., 2004a).

In 2005, disagreements over proposed changes to forest and fuels management actions by the USDA Forest Service (2004) prompted a coalition of conservation groups to file a successful lawsuit (Sierra Nevada Forest Protection Campaign et al., versus

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Mark Rey et al., 2005) challenging the changes, which included more aggressive forest thinning, increased harvest of large trees to finance the non-commercial thinning, and decreased protections for fishers and other sensitive species. In the context of this conflict, we were asked to perform an independent assessment of the status of the southern Sierra Nevada fisher population, an evaluation of the relative cumulative effects of fires and fuels management actions on the population, and habitat management approaches to help sustain the population. The analytical process was purposely transparent and responsive to input and guidance from stakeholders on all sides of the conflict – including forest managers, conservationists, scientists, and timber industry representatives – in attempt to ensure all parties agreed with the goals, assumptions, and procedures used in the assessment.

This paper presents results of simulation models we used to assess the status of the southern Sierra Nevada fisher population and to investigate opportunities and constraints for increasing the population's size and distribution via conservation and management actions. To accomplish these goals, we coupled a spatially explicit resource selection model with a spatially explicit population model. We used simulations and sensitivity analyses to estimate the population's potential carrying capacity under various assumptions and to identify potential population source, sink, and expansion areas. Results are being used as hypotheses to test with field research; they also provide spatially explicit information concerning where vegetation management actions may most benefit fishers.

2. Methods

We modeled fisher probability of occurrence at the home-range scale using generalized additive models (GAM) and population dynamics using the spatially explicit population model PATCH (Schumaker, 1998). In coupling these models, we assumed that fisher probability of occurrence strongly correlates with habitat value, and hence fitness, as reflected in differences in births and deaths averaged over time. The ability to scale demographic rates with GIS-predicted habitat value in this manner is a major strength of using spatially explicit population models like PATCH to evaluate conservation issues at the landscape or population scale (Schumaker, 1998; Carroll, 2006). It allowed us to vary model assumptions and parameter values to evaluate their likely effects on the population's size, distribution, and dynamics, and to identify potential population source, sink, and expansion areas.

2.1. Study area

The study area comprises 2,336,171 ha, including all known occupied fisher habitat in the southern Sierra Nevada plus potential, unoccupied habitat that may be important to sustaining or expanding the population, or that may contribute to fires that burn into fisher habitat. The study area includes substantial portions of three national forests (Sierra, Sequoia, and Stanislaus NF) and two national parks (Yosemite and Sequoia–Kings Canyon NP) plus surrounding private and tribal land. The area consists of steep and rugged terrain, from about 30–4400 m elevation, mostly west of the Sierra Nevada crest. Vegetation ranges from chaparral and oak woodlands at lower elevations, to mixed coniferous (pine and fir) forests in middle elevations, to subalpine and alpine communities at upper elevations. Due to California's Mediterranean climate, most precipitation falls as winter rain (at lower elevations) or snow (at higher elevations).

The northern end of the fisher population is in the westernmost portion of Yosemite NP. Fisher were rare to uncommon in the Park in the early 20th Century, when they were affected by commercial trapping, predator control, and logging both inside and outside the Park. Although trapping, predator control, and logging were discontinued in the Park in the 1920s and 1930s, the population apparently has not increased and is currently considered rare in the Park (Chow, 2009). Verified fisher observations since the early 1990s are few and almost exclusively within a narrow elevation band on the western edge of the Park, south of the Merced River Valley (also known as Yosemite Valley) (Chow, 2009).

2.2. Fisher probability of occurrence model

We modeled fisher probability of occurrence using GAM (calculated using the MCGV package version 1.3-30 for R version 2.70) applied to a wide array of environmental variables and systematically collected fisher detection–nondetection monitoring data (Truex and Seels, 2006; USDA, 2006). The monitoring surveys use fixed arrays co-located with Forest Inventory and Assessment (FIA) plots (Zielinski et al., 2006) within the three national forests (NF). The arrays are sufficiently spaced (~5 km apart) to represent independent samples of detected fishers. Each array consists of a central track station surrounded by five track stations positioned ~500 m from the central station at 72° intervals to form a pentagonal sample unit. Tracks were collected from each array every 2 days during a 10-day survey period, for five sample visits per survey. The probability (P) of a single survey at an array detecting a fisher if one is present is estimated to be 0.922 based on a per visit probability of detection (p) of 0.40 and $v = 5$ visits, using the equation $P = 1 - (1 - p)^v$ (Royle et al., 2008, p. 300). Each array is generally surveyed every other year between June and September. Most arrays were sampled between two and four times from 2002 to 2006.

Although there are 276 total arrays within the study area, we only used monitoring results from south of the Merced River ($N = 228$) to build occupancy models. Fishers have not been detected north of the Merced by the regional monitoring program or other systematic surveys, despite apparently suitable habitat there (although there are occasional unverified sightings and tracks north of the Merced but south of the Tuolumne River; L. Chow, personal communication). Absence of fishers north of the Merced could be due to historical extirpation and inadequate emigration from occupied areas, rather than lack of suitable habitat conditions (Jordan, 2007; Barrett, personal communications). Therefore, detection–nondetection data south of the Merced were used to create the GAM models, and results were projected north of the Merced to predict habitat potential.

We defined two different fisher response variables from the survey data for model building and testing: (1) MAPE (short for *MArtes PEnnanti*) includes all survey arrays south of the Merced ($N = 228$) regardless of the number of sample years or fisher detections. Arrays with at least one detection (in any year) were classified as presence points; arrays with no detections across all years were classified as absence points. (2) MAPE2 ($N = 169$) omits any arrays that were sampled only once, or that were sampled repeatedly but with no more than one detection. Thus, presence points are defined in MAPE2 as those yielding detections in at least two survey years, and absence is defined as points sampled at least twice but with zero detections. We hypothesized that models built using MAPE2 as the fisher response variable may better discriminate locations that are persistently or reliably occupied by fishers from those that may be intermittently or transiently occupied, and thus that MAPE2 models should more strongly reflect habitat quality (and hence fitness) than MAPE models.

We created candidate GAM models using different combinations of potential predictor variables derived from Geographic Information System (GIS) data layers at 1-ha resolution (Table 1). Variable combinations were based on existing fisher occupancy