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Using routinely collected regional forest inventory data to conclude that resting habitat for the fisher (*Pekania pennanti*) in California is stable over ~20 years

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ABSTRACT

The conservation and management of species-at-risk requires periodically collecting information about their distributions and abundances. A comprehensive monitoring plan should, in addition to monitoring the population itself, also assess the status of habitat elements that are key factors in species survival. Places where animals seek safe and secure places to rest are such key habitat elements. We used previously published models to predict resting habitat for fishers (*Pekania pennanti*) throughout much of their range in California. Unique to this work is that the two models (northwestern California and southern Sierra Nevada) were developed using, as predictors, variables directly from a national plot-based forest inventory program called Forest Inventory and Analysis (FIA). Using these models, relative resting habitat suitability can be estimated at each geographically relevant plot in the FIA system every time the plot is resampled. We applied these predictive models to data collected at 3 time periods over an approximately 20 year period to evaluate the trend in predicted fisher resting habitat. None of the 8 national forests, 4 in the northwestern California region and 4 in the southern Sierra Nevada region – nor either of these 2 regions as a whole – exhibited trends in predicted resting habitat suitability that were significantly increasing or decreasing. Predicted resting habitat suitability tended to be lower on private land than public land, in both regions. As expected, plots that were disturbed by fire exhibited a decrease in resting habitat suitability but, surprisingly, the few plots within harvest unit boundaries had indistinguishable values before and approximately 7 years after the harvest. Using FIA data for future assessments of habitat value will avoid the significant cost incurred when the data need to be collected repeatedly using different data and a field protocol that may vary. We anticipate that the FIA program will continue to be the preeminent plot-based vegetation survey in the United States, and the data to run the resting habitat models will be available every 10 years. Moreover, access to routinely updated plot-based data provides the only way we can envision sampling something as fine-scaled as resting habitat over thousands of square miles of potentially suitable habitat. We hope our example encourages others to parlay the FIA data into a predictive model of fine-scale habitat features that is relevant to other species. Demonstrating the utility of our models should also encourage managers to use the predictions to evaluate the status of fisher habitat in California.

1. Introduction

The conservation and management of species of concern requires information about the status and trends of key elements of their habitat. This, however, is a practical and financial challenge when the need is to monitor specific habitat conditions or elements over large and heterogeneous areas. Typically the only feasible approach is to develop a predictive model that relates remotely sensed characteristics of large, coarsely labeled vegetation polygons to general habitat value (e.g. Guisan and Zimmerman, 2000; Nijland et al., 2015; Westover et al., 2016). More difficult to assess over large areas are changes to the important, but localized, microhabitat elements such as nest sites or resting or roosting sites. These microhabitat features can be essential, but are exceedingly difficult and expensive to assess and monitor over large regions.

Given these constraints, the response to this dilemma is to develop a predictive model that estimates the relative value of habitat elements and track them over time. The traditional approach to doing so, however, has been to collect microhabitat data at used and random locations using a *researcher-derived* protocol for measuring the vegetation

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and topographic covariates to be used as predictors. Examples include a number of papers to which the senior author has contributed (e.g., Slauson et al., 2007; Zielinski et al., 2004a,b). These models generate unique predictors selected by the researcher that help us understand habitat needs but are often measured only once using the researcher's biologically relevant, but often singular, methods. In these cases field data on the model predictors are rarely collected on subsequent occasions, particularly over large regions, making it difficult to use the model to assess the future status of habitat elements as they change. New initiatives, however, have exploited the efficiency of publicly available, routinely resampled, plot-based vegetation databases as the sources for predictors for wildlife habitat models (e.g., Dunk et al., 2004; Huff, 2006; Fearer et al., 2007; Welsh et al., 2006; Dunk and Hawley, 2009; Twedt et al., 2010). The use of vegetation data that are collected regularly over time as part of a reliable government inventory program provides serial remeasurement of the predictors, and serial estimates of microhabitat conditions. Not only will this be more efficient but it may be the only way to assess the status and change in specific habitat elements over large regions.

The fisher (*Pekania pennanti*) is an uncommon carnivorous mammal in the Mustelidae that is of conservation concern in the western United States, as evidenced by multiple petitions for listing under the US Endangered Species Act. Fishers are among a wide variety of species of wildlife that use cavities or chambers in live and dead trees as daily refugia and for reproduction (Zielinski et al., 2004a; Lofroth et al., 2010; Weir et al., 2012; Green, 2017). These resting and denning (reproduction) structures are most typically the largest diameter standing live trees, snags, or logs (conifers and hardwoods) available (Zielinski et al., 2004a; Purcell et al., 2009; Lofroth et al., 2010; Aubry et al., 2013) yet other woody features, such as platforms of branches or mistletoe in tree canopies, can constitute a significant minority of resting locations (Seglund, 1995; Green, 2017). Cavities are typically in large trees and are considered one of critical elements for the maintenance of fisher populations (Paragi et al., 1996; Purcell et al., 2009; Lofroth et al., 2010; Weir et al., 2012; Green, 2017) and these features may take hundreds of years to develop. As a result there is a premium on information about the amount and distribution of resting habitat because it can be degraded at a much higher rate than it develops.

The conservation of fisher populations requires an understanding of their habitat ecology and the development of population and habitat monitoring programs. Native fisher populations occur in California in the southern Sierra Nevada Mountains (hereafter "southern Sierra" or SSN) and in the mountains of northwestern and northcentral California (hereafter "northwestern California" or NWCA) (Lofroth et al., 2010). Monitoring populations directly is a key component of any conservation strategy and a comprehensive program to monitor the status of the fisher *population* in the southern Sierra has been underway for approximately 15 years (Zielinski et al., 2013; US Forest Service, 2015). An analogous program to monitor the population in northwestern California, however, has not been undertaken. Although this shortcoming should be addressed, even if both regions had *population* monitoring programs, without a companion *habitat* monitoring program it is impossible to know whether a change detected in population is caused by a change in habitat condition, or some other factor. Despite this need, no program is in place to monitor changes in fisher habitat quantity or quality in either of the major regions of fisher occurrence in California.

We have previously developed empirical models that predict resting habitat value for fisher populations in both regions using plot data from publicly available and routinely remeasured vegetation inventory data (Zielinski et al., 2006; Zielinski et al., 2010; Zielinski et al., 2012). This was accomplished by integrating models of fisher habitat associations with the Forest Inventory and Analysis (FIA) forest inventory program (Reams et al., 1999; Bechtold and Patterson, 2005; Gray et al., 2012). The FIA program is a nationwide, probability-based sampling scheme designed to inventory and monitor natural resources. The design consists of sample points located in a systematic hexagonal grid (with centers of hexagons 5.47 km apart for one point per 2400 ha) across all ownerships in the United States with the goal of measuring environmental variables at sample plots every 10 years in the western U.S. (Bechtold and Patterson, 2005). FIA data are most often used to assist in planning forest management activities and monitoring forest composition, structure and disturbance. However, the FIA data are an attractive option for assessing and monitoring wildlife habitat because they are a temporally and spatially reliable source of field-measured habitat data across large regions. Moreover, the FIA program has long-term institutional support for resampling these plots. Although we have developed fisher resting habitat models that are linked to these inventory data, and have demonstrated their utility for monitoring this important habitat across individual national forests (i.e., Zielinski et al., 2010 see Fig. 2 therein), we are unaware of this information being used to inform project plans on national forests or as foundation in updating land management plans. Thus, here we use the most recent three cycles of FIA data available in each region to estimate regional trends in resting habitat suitability over a ~20-year period. In addition to estimating change in fisher resting habitat over a large portion of their range in California, our work should demonstrate the untapped potential of FIA data, which when linked to a predictive habitat model can be used to evaluate how disturbances such as timber harvest and fire affect the relative suitability of wildlife habitat.

2. Methods

2.1. The FIA-based fisher resting habitat models

The foundation for this work are two predictive resting habitat models for fishers that use variables from the FIA plot sampling protocol as predictors – one built from field data collected from fishers and their resting locations in the southern Sierra (Zielinski et al., 2006) and one from data collected in northwestern California (Zielinski et al., 2012). Building a predictive habitat model requires a comparison of characteristics at *used* locations (i.e., the sample of resting structures) with those that are *available* in the sample of regularly sampled FIA pots in the general vicinity of the resting structures. The southern Sierra model was built using data from plots centered on 75 randomly selected fisher resting structures as well as similar data from 232 of the nearby and regularly sampled plots in the FIA system, whereas the northwestern California model was built using plots centered on 99 randomly selected fisher resting structures and 883 nearby plots in the FIA grid.

The resting structures that were sampled to create the models were originally located during the course of two studies on the habitat ecology of fishers in the southern Sierra and two studies in northwestern California (Fig. 1) and were used by males and females. In the southern Sierra, the first study was conducted from 1994 to 1996 in the Sequoia National Forest in Tulare County (Zielinski et al., 2004a,b) and the second from 1999 to 2000 in the Sierra National Forest, Fresno County, California (Mazzoni, 2002) (Fig. 1). In northwestern California, the first study had two sub-areas and was conducted from 1993 to 1997 on the Six Rivers and Shasta-Trinity National Forests in Humboldt and Trinity Counties (Zielinski et al., 2004a,b; Fig. 1) and the second was conducted from 1996 – present on the Hoopa Valley Tribal Reservation (Higley and Matthews, 2009). Animals were captured, fitted with radio-transmitter collars and tracked on foot to their resting locations approximately once per week. Details regarding handling and telemetry methods are available elsewhere (Zielinski et al., 2004a,b). None of the resting structures were known to be used for the birth or care of young (i.e., dens).

Vegetation attributes at fisher resting locations were measured using the FIA vegetation sampling protocol (USDA Forest Service, 2007; Christensen et al., 2016) by surveyors that were also contracted to measure the regularly sampled FIA plots. At resting locations the plot was centered on the resting structure. The FIA protocol involves the collection of vegetation data at four or five subplots (see details