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Red-tree vole habitat suitability modeling: Implications for conservation and management

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ABSTRACT

In the Pacific Northwest, USA, red-tree voles (*Arborimus longicaudus*) are of conservation and management interest owing to their apparent association with late-seral forests and the relatively small extent of such forests, largely a function of timber harvest, fire, and conversion of forests to non-forest uses during the past century. We created and evaluated a series of red-tree vole habitat association models, and applied the best model to evaluate tree vole habitat quality within and outside of reserves throughout most of their range in Oregon and northern California. We modeled presence and absence of tree vole nests across a gradient of biotic, abiotic, and spatial features; and within and outside of reserves. The best model included spatial coordinates, percent slope, basal area of trees with diameter at breast height (dbh) between 45 and 90 cm, maximum tree dbh, and standard deviation of conifer dbh. Plots with tree vole nests contained many late-seral/old-growth forest attributes such as large diameter, older, and variably sized trees. Evaluation of the best model, including rigorous cross-validation, showed the model to be statistically robust and to have very good/excellent predictive ability. Reserves had significantly higher mean habitat quality than non-reserved lands, and reserves had much more high quality habitat than non-reserves.

1. Introduction

Tree voles (*Arborimus* spp.) are the most specialized voles in the world (Maser et al., 1981) and yet one of the most poorly understood mammals endemic to the temperate forests of the United States' Pacific Northwest (Forsman et al., 2004). Several life history traits may limit the ability of tree voles to withstand timber harvesting practices which often create fragmented landscapes characterized by young forests (Huff et al., 1992; Biswell and Forsman, 1999; Forsman et al., 2004). Tree voles: (1) live in conifer forests and forage on conifer leaves (Taylor, 1915; Howell, 1926; Benson and Borell, 1931); (2) have exceptionally long gestation periods, small litters, and slow juvenile growth rates (Hamilton, 1962); (3) have a relatively small geographic range (Johnson and George, 1991); (4) have limited dispersal abilities (Biswell et al., 2000; Swingle, 2005). Although tree voles do occur in young forests (Taylor, 1915; Howell, 1926; Benson and Borell, 1931; Maser, 1966; Thompson and Diller, 2002; Swingle, 2005), many researchers have suggested that they are habitat specialists primarily associated with mature and old forests (Corn and Bury, 1986; Raphael, 1988; Carey, 1989; Aubry et al., 1991; Gilbert and Allwine, 1991; Ruggiero et al., 1991; Gomez and Anthony, 1998; Biswell and Forsman, 1999; Jones, 2003). Carey (1991) and Huff et al. (1992) suggested that tree vole populations in young forests were not self-sustaining, and that such habitats were population sinks. In contrast, Swingle (2005), cautioned against the blanket assumption that young forests are always population sinks and urged managers to consider young forests as potential habitat for tree voles, especially in areas where old forests are rare. Despite research efforts, uncertainty still exists regarding basic ecological questions, namely their distribution and relative abundance in different forest types across their relatively small geographic range (Forsman et al., 2004).

There are two tree vole species, the Sonoma tree vole (*Arborimus pomo*) in California and the red-tree vole (*Arborimus longicaudus*) in Oregon and northern California (Johnson and George, 1991; Bellinger et al., 2005). The boundary between the two species is approximately the Klamath River in northern California, but the exact boundary and taxonomic relationships between the two species are still not fully resolved (Johnson and George, 1991; Bellinger et al., 2005; Miller et al., 2006). Although morphological and genetic distinctions exist between these two

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species, no apparent ecological differences have been discovered (Johnson and George, 1991; Smith et al., 2003).

The general lack of information on tree vole biology, their relatively uncommon occurrence in young forests, and concern that forest fragmentation would lead to the development of isolated subpopulations all contributed to their being listed as a "Survey and Manage" (hereafter SM) species under the Northwest Forest Plan (USDA/USDI, 1994; hereafter NWFP). The NWFP was an unprecedented attempt by the federal government in the U.S. to manage ~10 million ha of federal land in Washington, Oregon, and northern California as an ecosystem (USDA/USDI, 1994). The red-tree vole was one of >400 species, and the only mammal, initially listed as a SM species. The SM provisions attempted to protect taxa that were believed to: (1) occur within the NWFP area; (2) be associated with late-seral/old-growth forests; (3) not be adequately protected within the reserve system set up under the NWFP, a system designed largely using quantitative data on the northern spotted owl (*Strix occidentalis caurina*) and qualitative data and expert opinion on >1000 other species. The second and third assumptions were not specifically tested prior to listing any species as SM, but expert opinion and, when available, scientific information informed the listing process. Prior to on-the-ground management activities (e.g., timber harvest, road removal, controlled fire), land managers were often required to *survey* for SM species, and to *manage* for their continued occurrence if they were found (USDA/USDI, 1994). Finding, monitoring, and managing for rare, cryptic, and elusive species is extremely difficult and expensive (Raphael and Molina, 2007). Furthermore, the relatively small spatial scale of most studies limits the area to which scientifically valid inferences can be drawn. Lastly, study-specific measurements (e.g., the suite of biotic and/or abiotic features that are estimated) and protocols, often prohibits direct application of research findings by land managers.

To address these difficulties and shortcomings, we sampled for red-tree vole (hereafter, RTV) nests across most of their range, including the potential zone of overlap between *A. longicaudus* and *A. pomo* in northern California. Sample sites were co-located at pre-existing plots at which vegetation data are routinely collected (see Section 2). We modeled the presence–absence of RTV nests at these sites, and extrapolated the model to all plots at which vegetation data existed within the range of the RTV. In order to quantify the value of the NWFP reserves to tree voles, we evaluated the quality of RTV habitat in reserved and non-reserved lands. We provide a quantitative method for monitoring RTV habitat quality and distribution over time (by applying our model to the plots that are periodically re-sampled), and a quantitative evaluation of two of three SM criteria: the species' presumed association with late-seral/old-growth forests, and an evaluation of the habitat value within reserved and non-reserved lands. In part, this last evaluation is an indication of the value of the northern spotted owl as an umbrella species (Dunk et al., 2006).

2. Methods

2.1. Study area

The study area included approximately 2.7 million ha of land in western Oregon and northern California. It included nearly the entire range of the *A. longicaudus* except for portions of the northern Coast Ranges and northern Cascades in Oregon (Fig. 1). The study area included forest lands sampled in the following physiographic regions: Oregon Coast Range, Middle Cascade Mountains, and the Klamath Mountains in Oregon and California, and the Coast Range in California. Generally, areas near the coast are cooler year-round, with more extreme summer highs and winter lows along west to east gradients. Similarly, general gradients from more xeric to more mesic conditions exist from south to north.

Topography throughout the study area is generally steep and rugged. Land use history is quite varied, with large areas of intensive silviculture operations and large areas of reserved lands with little-to-no evidence of silvicultural operations. Similarly, forest structure and age varied dramatically, ranging from recently logged areas to 600-year-old structurally complex forests that have never been logged.

2.2. Vegetation data

We acquired vegetation data from 1003 Current Vegetation Survey (CVS) and Forest Inventory and Analysis (FIA) plots within the range of the RTV (USDA, 2001a,b; http://www.fs.fed.us/r6/survey/document.htm; http://www.fs.fed.us/pnw/fia/publications/fieldmanuals.shtml). These plots are systematically spaced on Federal lands at intervals of ~2.7 km in Oregon and ~5.5 km in California (Fig. 1), and are re-sampled every 10 years to monitor regional changes in vegetation (USDA, 2001a,b). Standardized physiographic and physiognomic information was collected at each site, creating an extensive database available to land managers for monitoring changes on the landscape in response to management practices and natural phenomena.

Although many vegetation variables are measured at CVS/FIA plots (USDA, 2001a,b; http://www.fs.fed.us/r6/survey/document.htm; http://www.fs.fed.us/pnw/fia/publications/fieldmanuals.shtml), we extracted only those variables known or suspected to be important to tree voles. We evaluated published and unpublished papers, spoke with field researchers, and used our own field experience with the species to identify variables used in the analyses. Only plot-level data were used to estimate biotic variables.

2.3. Estimating red-tree vole nest presence and abundance

From the 1003 CVS/FIA plots on Federal lands within the range of the RTV, a spatially balanced stratified random sample of 400 plots were selected in which the number of trees containing tree vole nests was estimated (Rittenhouse et al., 2002). Ultimately 368 of these plots were sampled for voles, with 32 plots being eliminated because of logistical or safety reasons. Plots were stratified based on habitat (late-successional and old-growth forests [LSOG] vs. non-LSOG) and whether the plot fell within a reserve or not. LSOG status was determined based on mean tree age >80 years. Allocation of plots by LSOG/non-LSOG and reserve/non-reserve was as follows: reserve/LSOG = 60%, reserve/non-LSOG = 20%, non-reserve/LSOG = 10%, and non-reserve/non-LSOG = 10%. Our goal was to evaluate red-tree vole habitat associations via the development and testing of multiple competing models, which we are reporting here. Of 368 sampled plots, we were able to use FIA/CVS data from 365 plots (data were unavailable for 3 plots).

RTV surveys were conducted between October 2001 and October 2004. Within each square 1-ha plot, at least two trained observers conducted visual searches for tree vole nests while walking along four transects that were spaced 25 m apart. When either fecal pellets, resin ducts, or potential nests were observed, vole nests were confirmed by climbing trees and examining all potential nests to see if they contained evidence of occupancy by tree voles (fecal pellets, resin ducts, and confer branch cuttings). A major concern with ground-based surveys of tree vole nests is that significant numbers of nests may go undetected, especially in old forests where many nests are so high in the canopy that they cannot be detected from the ground (Swingle, 2005). Therefore, to reduce the number of false negatives (no vole nests detected in a