Mesocarnivores as Focal Species for the Restoration of Post-Logging Second Growth in the Northern Redwoods

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Abstract

The management of second growth forests to accelerate the restoration of late-successional and old growth characteristics will be one of the greatest challenges for conservation in the redwood region over the next century. In the redwood region, the largest complex of protected areas exists in the north, however >50 percent of these forest reserves are composed of logged, degraded second growth forests. Strategic restoration actions have the potential to accelerate the restoration of old growth forest characteristics and the old growth forest species assemblage that requires these features. Restoration actions in degraded aquatic habitats over the last two decades have been guided by the needs of several salmonid species. Currently there are no guidelines for how to strategically restore second growth forests based on the needs of old growth dependent wildlife species. We developed a focal species approach to provide restoration guidelines based on the spatial and compositional needs of the Humboldt marten (*Martes americana humboldtensis*), a mesocarnivore sensitive to the loss and modification of old growth forest conditions. In addition, two marten predators – the fisher (*Martes pennanti*) and bobcat (*Lynx rufus*) – were selected because they likely expanded their range or abundance, respectively, following the extensive logging of the 1900s. Successful restoration of the old growth forest mesocarnivore assemblage in the redwood region will require an increase in the amount and connectivity of old forest conditions and reduction of road densities which should result in the expansion of the remnant Humboldt marten population and decreases in the range and abundance of the fisher and bobcat.

Key words: *Martes*, Humboldt marten, marten, mesocarnivores, second growth, restoration, focal species, redwood forest management

Introduction

State of forest reserves of the redwood region

More than 95 percent of the primary, old growth, forests of the redwood region have been logged (Fox 1996, Thornburg et al. 2000) and dramatically altered from what it resembled in pre-European settlement times. Forest reserves, defined here as tribal, state, or federal agency administered lands with the primary goal of maintaining or restoring late-successional and old growth forest characteristics, include <20 percent of the redwood region but are composed of >50 percent logged and degraded, second growth forests (Noss et al. 2000). The greatest concentration of forest reserves occurs in the northern redwood region. Currently Redwood National Park includes >50,000, California State Parks >20,000, Yurok Tribe >15,000 and the Six Rivers National Forest >10,000 ac of fog-influenced second growth forest (California State Parks 2010, Keyes 1995). Collectively, the degraded portions of

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these forest reserves provide the greatest opportunity to restore a large-scale example of the fog-influenced forest ecosystem in the redwood region.

Focal species approach for restoration design and biodiversity conservation

Attempts to restore such a large amount of second growth forest to old growth conditions are unprecedented globally. Restoration requires that either historical or desired conditions be defined and methods identified to reconstruct or accelerate the restoration of compositional and spatial elements towards those conditions. While studying the structure and composition of remnant stands of old growth can provide important information to guide the development of silvicultural treatments, this information alone will not adequately address the needs of many wildlife species. A focal species approach is necessary to identify key limiting compositional features and design restoration actions at large enough spatial. The first step in the application of the focal species approach is to select the subset of species most sensitive to the loss and modification of the compositional and spatial characteristics of old growth forests. The habitat needs of the focal species are then used to guide restoration at all relevant spatial scales (Lambeck 1997). By selecting the suite of species most sensitive to the compositional elements and spatial amounts of old growth forests, they act as "umbrellas" for species that are less sensitive.

The focal species approach has already been in practice in guiding restoration actions in the stream and rivers of the redwood region. Salmonids, such as Coho (*Oncorhynchus kisutch*) and Chinook (*O.* tshawytscha), have been focal species and compositional elements, such as suitable spawning gravels and more recently in-stream large woody structures have been targets for restoration where they have been degraded or lost. Meaningful spatial scales for salmonid habitat restoration have focused on entire watersheds to reduce sedimentation sources and improving overall habitat conditions with the goal of providing the amount of habitat to support populations similar to those supported by historical conditions. Restoration actions for terrestrial habitats have been slower to develop, due in part to the lack of information linking terrestrial wildlife to critical habitat characteristics and the growing acceptance that thinning trees in forest reserves is an essential tool for accelerating the restoration of historical and desired conditions (DeBell et al. 1997, Tappeiner et al. 1997). Given the scale of the challenge of restoring large areas of second growth forest with limited resources, a strategic focal species approach will be necessary to optimize the goals of restoring old forest characteristics and the species that most require them. The objective of this paper is to identify a suite of focal species and use them as the basis for developing strategic restoration guidelines for the terrestrial second growth forests of the northern redwood region.

Methods

Process for selecting focal species

I first identified the suite of species that are unlikely to persist in the redwood region without restoration of features of *old growth forests*. Emphasis was given to taxa which are endemic or near-endemic, >75 percent of their distribution in the redwood region. However, taxa at risk (e.g., threatened or endangered) over larger areas were also considered. I did not consider populations that are secure, unless their presence was identified as being a threat to the persistence of a species at risk. Second, I identified the processes that have contributed to the decline in the abundance or distribution of each candidate species (*fig. 1*). Species with similar responses to processes were grouped and for each process, the most sensitive to the process was selected.

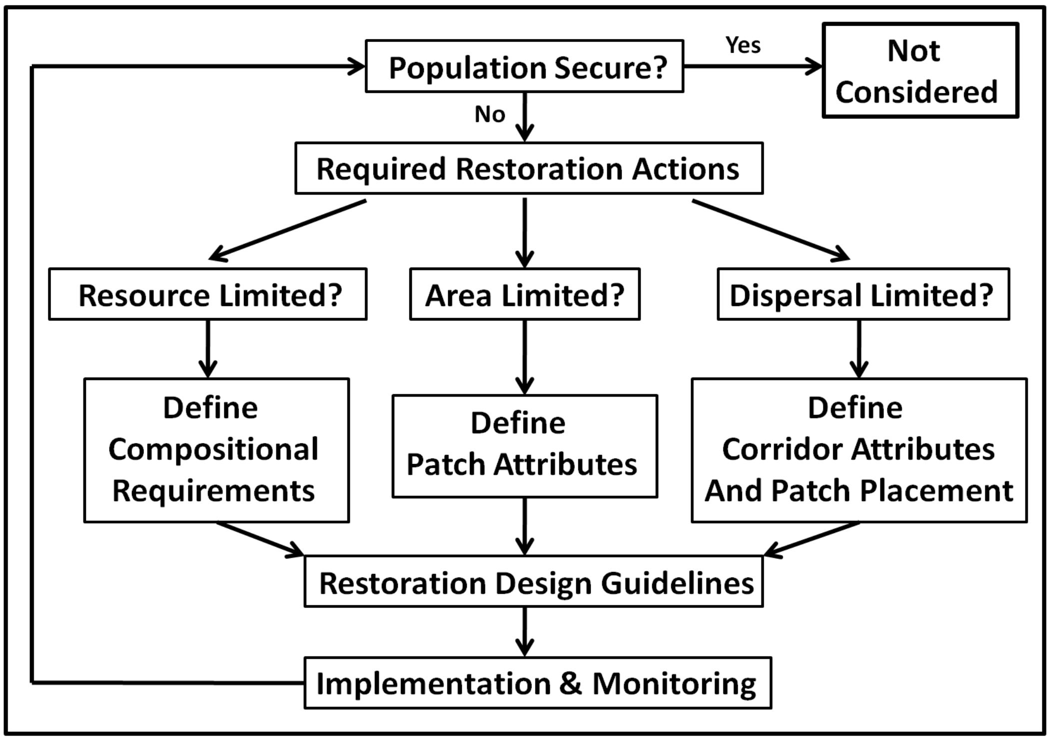

Figure 1—Schematic representation of the steps for the selection of focal species and development of restoration guidelines for reconstructing critical compositional and spatial habitat elements; modified from Lambeck (1997).

Steps for designing restoration guidelines

Landscape restoration and reconstruction will be required for species that are limited by (1) a shortage of critical resources, (2) an inability to move between suitable habitat patches, or (3) insufficient habitat to meet their resource needs or to support a viable population (Lambeck 1997). Once focal species were selected, the first step was to review and synthesize relevant literature on their ecology to identify limiting resources, area limitations, and dispersal limitations. Because everything about a focal species' ecology may not be known, areas of uncertainty were identified. Limiting resources are those that are linked to key life history requirements and lacking them precludes the species occurrence. Area limitations are those that lead to stable occupancy of at least one home range or breeding territory. Dispersal limitations are considered for both within subpopulation movements of individuals and between subpopulation movements.

Results

Focal species selection

Cooperider et al. (2000) identified 18 terrestrial or amphibious vertebrate taxa endemic or near-endemic to the redwood region. Of the nine that occur in the northern redwood region, I conclude only the Humboldt marten (*Martes americana humboldtensis*) is not likely to persist without restoration actions. The Humboldt marten has been extirpated from >95 percent of its historical range and persists in a single population numbering <100 individuals (Slauson et al. 2009b). The remaining eight near-endemic vertebrate taxa are either not strongly associated with old growth forest characteristics (e.g., fog shrew [*Sorex sonomae sonomae*], Pacific coast Aquatic garter snake [*Thamnophis attratus attratus*], California giant salamander [*Dicamptodon ensatus*]), have populations supported on forests managed for timber production (e.g., California tree vole [*Arborimus pomo*]), or have comparatively secure populations in forest reserves (e.g., Del Norte salamander [*Plethodon elongatus*], Wandering salamander [*Aniedes vagrans*]; Cooperider et al. 2000). In addition to the marten, the marbled murrelet (*Brachyramphus marmoratus*) and northern spotted owl (*Strix occidentalis caurina*) are of conservation concern and have significant portions of their populations in the redwood region that likely influence their population status beyond the redwood region. While spotted owls and marbled murrelets are also potential candidates as terrestrial focal species, the remainder of this paper focuses on mesocarnivores.

The loss of old growth forest in the redwood region is the chief process that has driven the decline of the Humboldt marten (Zielinski et al. 2001). While extensive trapping in the late 1800s and early 1900s was the initial driver of population decline for the Humboldt marten (Grinnell et al. 1937), despite the closure of the trapping season for >50 years or approximately 10 marten generations only a single population remains in <5 percent of its historical range. The remnant marten population has been unable to recolonize adjacent areas of second growth forest, or to disperse across second growth landscapes to recolonize suitable old growth patches (Slauson and Zielinski 2003).

In addition to the direct loss of old growth forests, the fragmented state of the remaining old growth forests further threatens population stability and growth for the marten. Highly fragmented habitat is more likely than contiguous old growth habitat to support unstable marten occupancy (Slauson et al. 2010). At the landscape scale, the largest remaining patches of old growth habitat suitable for martens to recolonize are currently too far apart and exist in a second growth matrix not compatible for marten movement and dispersal.

Second growth forests in the northern redwood region up through at least 60 years old support a highly altered mesocarnivore assemblage, dominated by species known to or capable of preying on martens. The conversion of the northern redwood region from primarily old growth to young second growth has facilitated the expansion of the range of the fisher (*Martes pennanti*) and increases in the abundance and distributions of bobcats (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*). Grinnell et al. (1937) identified the range of the fisher as distinctly inland from the coast and largely on the eastern edge of the redwood region. While some have questioned Grinnell et al.'s (1937) historical range of the fisher in coastal California (DFG 2010), the absence or rarity of fishers in coastal forests is both consistent with their continental distribution (Giblisco 1994, Proux et al. 2000) and present day habitat associations from surveys conducted in the redwood region (Klug 1996, Slauson and Zielinski 2003). In the last century, fishers have expanded their range west and can now be detected near the ocean in second growth forests (Slauson and Zielinski 2003). Surveys within the largest remaining patches of old growth forest, including the area occupied by the remnant marten population, indicate fishers either do not occupy or only use stands near their edges (Slauson and Zielinski 2003). While historical information on range and abundance for bobcats and gray foxes is not as detailed as that for fishers, the pattern of their detections occurring largely in second growth but rarely in the cores of remnant old growth patches mirrors that of the fisher (Slauson and Zielinski 2007; K. Slauson, unpublished data).

Of the six studies reporting 57 predation events on marten in North America, mammalian carnivores were responsible for 75 percent, with bobcats (44 percent), coyotes (19 percent), and fishers (11 percent) the most frequent predators (Bull and Heater 2001, Ellis 1997, Hodgeman et al. 1997, McCann et al. 2010, Raphael 2004, Thompson 1994). Restoration actions will need to also result in the reduction in occupancy and abundance of marten predators in order to be successful in restoring martens and the coastal old growth mesocarnivore assemblage. Therefore, I propose the fisher, a forest specialist, and bobcat, a habitat generalist, as additional focal species.

Resource limitations

Second growth forests are depauperate of two critical resources for martens, dense shrub cover and suitable resting/denning structures. Restoration prescriptions for critical resources should be applied at the stand scale. Larger spatial considerations will follow, see Area Limitations below, such that stand scale restoration prescriptions can be aggregated to meet larger scale needs of focal species.

Dense, spatially extensive shrub cover is a critical component of suitable habitat for the Humboldt marten and >95 percent of all detections (n = 50; Slauson et al. 2007, Slauson et al. 2009b), rest sites (n = 55; Slauson and Zielinski 2009a), and active telemetry locations (n = 235; K. Slauson unpublished data) have occurred in stands that support it. Dense, spatially extensive shrub cover is a common understory structural layer in mature forests in the northern redwood region (Sawyer and others 2000). Martens typically occupy old growth stands with shrub layers that average >70 percent cover, are dominated by long-lived shade tolerant species (e.g., evergreen huckleberry [*Vaccinium ovatum*], salal [*Gaultheria shallon*]), and form continuous structural layers that spread throughout and between adjacent forest stands (Slauson et al. 2007). Shrub layers provide multiple direct and indirect benefits to martens including: berries for food, overhead cover from avian predators, cover from larger-bodied mesocarnivores, and mast that supports prey population. Slauson and Zielinski (2007) measured shrub cover in >800 plots in northwestern California and found that dense shrub cover has been significantly reduced in logged second growth forests <20 km from the coast.

Martens use resting structures daily between forging bouts to provide secure locations to sleep, conserve energy, and in some cases consume prey. Martens show little short-term re-use of structures and thus require many resting structures throughout their home ranges to provide resting locations close to where they are foraging and to provide for seasonal thermoregulatory needs (e.g., platforms in summer for cooling, cavities and chambers in winter to provide refuge from precipitation and warmth; Schumacher 1999, Taylor and Buskirk 1994, Wilbert 1992). Humboldt martens select large live and dead woody structures, including snags, logs, and live trees, that are typically >90 cm in diameter (Slauson and Zielinski 2008). Slauson et al (2010) found second growth stands in the Lost Man creek watershed and Mill creek watershed contain no suitable live tree structures and <10 percent the density of suitable snag structures compared to old growth stands occupied by martens. Further, compared to marten occupied stands, suitable downed log densities were similar in the older second growth stands in the Lost Man creek watershed but were <20 percent of the densities in the Mill creek watershed. Natural recruitment of suitable resting structures will likely not begin for >2 centuries, as most resting structures used by martens were of greater age when living (Slauson and Zielinski 2009a).

Area limitations

In California, martens maintain home ranges of approximately 300 ha to provide for their year-round resource needs (Spencer et al. 1983). While Humboldt martens use stands other than old growth for foraging, a large patch of old growth forest is a prominent component of their home ranges (K. Slauson unpublished data). Humboldt martens are highly selective for patches of old growth habitat >100 ha (Slauson et al. 2007). Patches <150 ha supported unstable marten occupancy (Slauson et al. 2009b). Restoration actions that enlarge existing small patches of old growth habitat may be the most effective in the short term while designing stand scale restoration actions to aggregate into patches of >150 ha will provide for the development of patches that cam become the cores for new home ranges once suitable conditions are restored.

Dense road networks are ubiquitous in second growth areas. The Humboldt marten makes little use of roads (Slauson et al. 2010) and does not occupy areas with high roads densities (Slauson 2003). Roads fragment the dense understory shrub layers and create networks of edge habitat that has no natural precedent in coastal forests. Slauson et al. (2010) found that >75 percent of habitat generalist species detections occurred on roads and were dominated by bobcats and gray foxes. The development of roads created networks of edge habitat that has likely facilitated the increase in distribution and /or the abundance of bobcats and gray foxes in second growth landscapes. Furthermore, encounters between martens and potential predators on roads may lead to higher rates of predation as martens will be farther from escape cover (e.g., tree boles for climbing) than encounters in forest interiors. Without minimizing or eliminating road networks, martens may not become re-established in areas where other suitable habitat characteristics have been restored.

Dispersal limitations

Occupied marten home ranges typically do not occur in isolation from other adjacent marten home ranges, thus >150 ha patches should be aggregated into local clusters of ≥ four patches to provide enough habitat to support adjacent home range establishment by multiple individuals of each sex. While martens are capable of long distance dispersal movements >50 km (e.g., Slough 1989), most martens that disperse and successfully establish home ranges move <5 km (Johnson et al. 2009).

Patch clusters should be located as close as possible to either occupied habitat or adjacent to other clusters < 5 km. Finally, initial restoration actions should be done in areas as proximal as possible to currently occupied habitat to increase the probability that restoration areas can be recolonized by martens once suitable conditions return.

Restoration design guidelines

Restoration actions that will benefit the regeneration of dense shrub cover include reducing overhead cover from trees by thinning. Thinning treatments conducted 30 years ago (see Keyes 2005, Veirs 1986) have restored shrub cover to a median value of 55 percent compared to <10 percent in unthinned control stands (Slauson et al. 2010). Recently thinned stands (2 to 7 years ago) in the Mill creek watershed of Del Norte Coast Redwood State Park have also significantly increased shrub cover to a median of 30 percent compared to <10 percent in unthinned stands. Without canopy thinning, most stands would likely lose shrub cover completely if left to self-thin, requiring re-establishment of shrub species from seed and many more decades before the shrub layer is restored.

Three methods may increase the number of resting structures in second growth habitats: enhancement, augmentation, and deployment of surrogate structures. Because these methods have not been developed for marten in the redwood region, these efforts should be initially undertaken in research and demonstration mode. Enhancement refers to creating suitable resting locations within existing structures such as using chainsaws to create cavities in downed logs and live trees of suitable size (e.g., Brown 2002). Augmentation refers to the transport of suitable structures to sites where they are deficient. This is likely the most expensive option as it requires both the acquisition of large diameter logs and deposition in target sites, necessitating the use of heavy machinery. The deployment of surrogate structures involves the building of artificial resting structures and placement in target stands. In Scotland, biologists have developed a marten den box has successfully provided the European pine marten with resting and even denning locations in forest stands where they are lacking (VWT 2010). Enhancement and the use of surrogate structures are likely the two techniques that if used in combination will provide the most cost effective methods to provide resting structures at large spatial scales. However, augmentation may be necessary in large areas where large diameter structures are particularly scarce.

Implementation and monitoring

One of the most critical phases of restoration projects is the monitoring that follows implementation to provide critical feedback to guide future restoration actions. While actions intended to restore critical habitat elements where they have been lost is founded in the ecology of the most sensitive species, success is not guaranteed. Therefore, post implementation monitoring will be critical for evaluating restoration actions and to provide any refinement for future restoration actions.

Discussion

The degraded state of much of the second growth forests in reserves cannot be left unmanaged due to the presence of many characteristics that are far outside the natural range of variability. Tree densities and species compositions depart greatly from those present in mature and old growth forests (Keyes 1995, Veirs 1986). Just as the threats of sediment delivery lead to actions to decommission dense roads networks in these forests for restoring salmonid populations, terrestrial habitats too will need restoration actions to reconstruct critical compositional and spatial elements to accelerate the restoration of habitat for sensitive the terrestrial fauna of redwood forests. In combination with silvicultural objectives and aquatic focal species restorations actions, an approach using terrestrial focal species provides a comprehensive and strategic basis for designing restoration actions with the best chance for restoring old growth forest communities and ecosystems northern redwood region.

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Northern California Redwood Forests Provide Important Seasonal Habitat for Migrant Bats

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Abstract
Bats are known to roost in redwood forests year-round, but their activities outside the summer season are poorly understood. To improve understanding of the use of redwoods by resident and migrant bats, we conducted 74 mist net surveys between February 2008 and October 2010. Captures were dominated by Yuma myotis (*M. yumanensis*) in the summer and silver-haired bats (*Lasionycteris noctivagans*) in the winter. During November-February, silver-haired bats, accounted for 78 percent of 23 captures and male:female sex ratio was (9:9). By contrast, during June-August, silver-haired bats accounted for 13.8 percent of 269 captures and sex ratios were highly male skewed (34:3). In combination with other regional information, this indicates that female silver-haired bats migrate to redwood forests. To infer summer locations of bats captured in redwood forests, we analyzed stable isotopes of hydrogen, carbon, nitrogen, and sulfur in their fur. Despite spatial segregation between male and female silver-haired bats during presumed molt period, we did not find differences between the sexes in range of isotope values in their fur. Nor were their values different from Yuma myotis. Our findings highlight some of the challenges in using stable istotope analysis to infer migratory pathways in bats.

Key words: bats, *Lasionycteris noctivagans*, *Lasiurus cinereus*, *Myotis yumanensis*, redwoods, stable isotopes, migration, winter

Introduction

Studies of bats in redwood forests have focused largely on their roosting ecology, in particular their use of basal hollows (Fellers and Pierson 2002, Gellman and Zielinski 1996, Rainey et al. 1992, Zielinski and Gellman 1999, Zielinski et al. 2007). A novel result of two of these studies was documentation of bat activity during winter (Gellman and Zielinski 1996, Zielinski and Gellman 1999). Autumn–spring is the period when temperate-zone bats engage in important activities that critically affect their annual energy balance such as migration, mating, and hibernation (Weller et al. 2009).

The silver-haired bat (*Lasionycteris noctivagans*, hereinafter LANO) is a tree-roosting species that is thought to undertake seasonal migrations between its summer and winter habitat (Cryan 2003). Male and female LANO are geographically segregated during the summer months throughout much of North America (Cryan 2003). In Douglas fir forests of northwestern California (hereinafter NWCAL) LANO was one of the most frequently captured species during summer; but captures were > 95 percent males (TJW unpublished data). The limited capture work in

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