# Chapter 7.1—The Forest Carnivores: Marten and Fisher

*William J. Zielinski*[1]

## Summary

Martens and fishers, as predators, perform important functions that help sustain the integrity of ecosystems. Both species occur primarily in mature forest environments that are characterized by dense canopy, large-diameter trees, a diverse understory community, and abundant standing and downed dead trees. Martens occur in the upper montane forests, where the threat of wildfire is less, and fishers predominately occur in the lower montane forests, where the threat of severe wildfire is much greater. Both species use habitat at multiple scales: the resting/denning site, the stand, the home range, and the landscape. Thus, management of habitat may benefit from considering these components when evaluating the effects of treatment activities. These species' diets are relatively diverse and their prey occurs in a variety of habitats within their home ranges. It appears that the heterogeneous conditions that are predicted to occur with the restoration of fire as a disturbance process may yield habitat for martens, fishers, and their diverse sources of food. New science, however, will be needed to test this assumption. Mechanical thinning may mimic some aspects of disturbance that would ideally be caused by fire, but this alternative would appear to be more justified—based on departures from fire return intervals—in the lower montane forests where fishers occur than in the upper montane forests where martens occur. During the course of mechanical treatments, however, it would be important to restore or maintain the distributions of large trees, conifers, and—for the fisher—black oaks, as well as sufficient understory habitat for both species. Management actions to reduce fire risk, or to restore ecological resilience to fire, may be consistent with the maintenance of landscapes capable of supporting fishers, as long as sufficient resting/denning structures are retained and the composition and configuration of the residual landscape is compatible with home range requirements. New scientific tools have been developed in the last 10 years to help evaluate the effects of proposed treatments on habitat features for fishers, in particular, but these have not yet been used in a coordinated manner to evaluate effects at multiple scales (resting/denning, home range, and landscape). Similar tools need to be developed to evaluate marten habitat. This chapter of the synthesis identifies the threats to each species in the Sierra Nevada and outlines the science available to assist managers in dealing with these threats. Our knowledge base is far from complete, however, which is why monitoring fisher and marten

[1] Research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Dr., Arcata, CA 95521.

populations and their habitats is an important centerpiece of their management. Monitoring, together with new ideas about adaptive management (especially for the effects of treatments on fishers and their habitat), is critical to ensuring that implementation of an ecosystem management scheme for the forests of the Sierra Nevada will benefit long-terms goals for marten and fisher conservation.

## The Important Role of Predators in Ecosystems

Predators have important effects on the structure of biological communities, primarily because the act of killing and eating other species transfers energy and nutrients through the ecosystem. However, they also have important indirect effects on community structure because their consumption of prey—and their simple presence—affects the distribution of herbivores, which, in turn, affects the abundance and distribution of plants. These "trophic cascades" have been most clearly demonstrated by research on the effects of the return of wolves to the Yellowstone ecosystem (Ripple and Beschta 2004). The retention of predators in an ecosystem is, therefore, integral to the maintenance of biodiversity and, hence, the resilience and proper functioning of that system (Finke and Denno 2004, Finke and Snyder 2010). In addition, when larger predators are absent, intermediate-sized (meso) predators can increase to the point that they have destabilizing effects on their prey, a phenomenon referred to as "mesopredator release" (Crooks and Soulé 1999, Roemer et al. 2009). The "top down" control of community structure by predators, which has been demonstrated on every continent and ocean, is primarily why researchers work to understand the ecology of montane mammalian predators and to collect information that will help ensure their persistence in the face of environmental change. California has already lost some key mammalian predators (e.g., grizzly bear [*Ursus arctos*], gray wolf [*Canis lupus*]), and some species are so rare that they no longer play effective ecological roles (i.e., wolverine [*Gulo gulo*] and Sierra Nevada red fox [*Vulpes vulpes necator*]). Thus, the disproportionately important functional roles of mammalian predators are already reduced in montane forest ecosystems in California, and elsewhere in North America (Laliberte and Ripple 2004). Using research results from studies on carnivores to inform management will help ensure that additional predators, especially the two species of forest mesocarnivores, the fisher (*Pekania pennanti*) and the Pacific marten (*Martes caurina*),[2] are not lost from our forest ecosystems and can continue their important roles throughout their geographic ranges.

**The retention of predators in an ecosystem is, therefore, integral to the maintenance of biodiversity and, hence, the resilience and proper functioning of that system.**

[2] Recent taxonomic revisions have changed the scientific names of the marten and fisher in California. What was formerly the American marten (*Martes americana*) in western North American is now the Pacific marten (*M. caurina*) (Dawson and Cook 2012). The fisher, which was formerly *M. pennanti*, is now *Pekania pennanti* (Sato et al. 2012).

This chapter considers the relevant science necessary to assist in the management of the fisher and Pacific marten. These are not the only species that could be affected by management decisions, but they are among the most prominent conservation concerns across many national forests in the synthesis area. A case could be made for the inclusion of the wolverine and the Sierra Nevada red fox species that have generated recent interest (Moriarty et al. 2009, Perrine et al. 2010), but given time and space limitations, this chapter is focused only on the fisher and the marten.

Zane Miller

Figure 1—Fisher in an incense cedar (*Calocedrus decurrens*), Fresno County, Sierra National Forest.

## The Fisher and the Marten in Context

The fisher, a medium-sized member of the family Mustelidae, is the only species in its genus and it occurs only in North America. Its dark brown, glossy fur often looks black. Fishers have white or cream patches on the chest and around the genitals, and the head and shoulders are often grizzled with gold or silver (Douglas and Strickland 1987). The conical shape of the tail, thicker near the body and tapering to a thinner tip, distinguishes the silhouette of the fisher from that of the Pacific marten, *M. caurina*; fishers also have relatively smaller ears than martens, and lack the marten's yellow or orange gular or ventral patches. There is a single subspecies of fisher in California, the Pacific fisher (*P. pennanti pacifica*) (fig. 2).

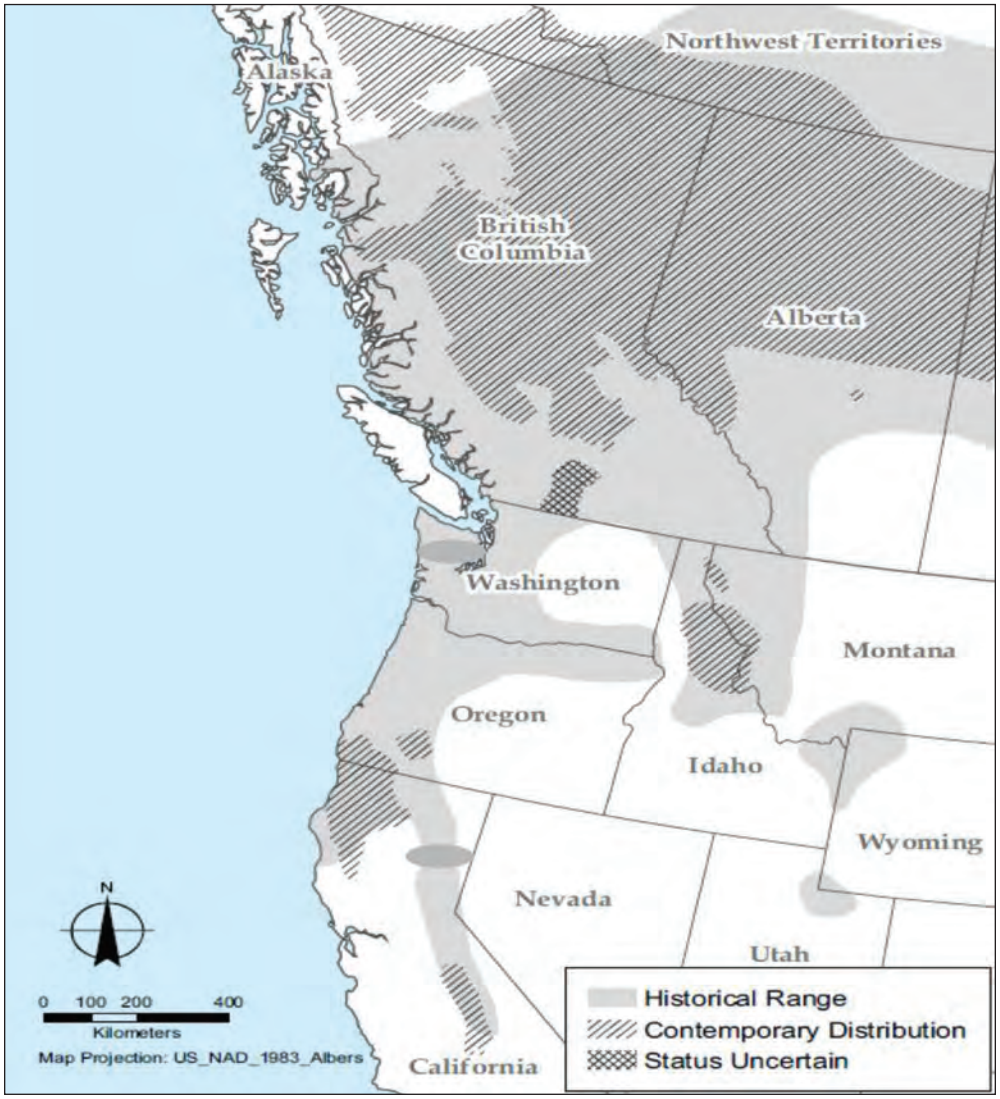


Figure 2—Fisher geographic range in western North American (adapted from Lofroth et al. 2010). Gray ovals in the Olympic Peninsula and in the northern Sierra Nevada refer to the locations of recent reintroductions.

There are 14 subspecies of marten recognized by Hall (1981) (fig. 3). Recent genetic and morphological evidence has warranted splitting the American marten into two species: the American marten east of the Rocky Mountain crest (*M. americana*) and the Pacific marten (*M. caurina*) west of the crest (Dawson and Cook 2012) (fig. 4). Two subspecies of the Pacific marten are recognized in California: the Sierra marten (*M. c. sierrae*) in the Sierra Nevada, Cascades, and Klamath/Trinity Mountains, and the Humboldt marten (*M. c. humboldtensis*) in the redwood zone along the north coast. For the purposes of this chapter, I hereafter refer to all martens in California as the Pacific marten (*M. caurina*), with most of the focus on the Sierra Nevada subspecies (*M. c. sierrae*).


Figure 3—The subspecies of marten in North America (from Dawson and Cook 2012, reprinted from *Biology and Conservation of Martens, Sables and Fishers: A New Synthesis*, Keith B. Aubry, William J. Zielinski, Martin G. Raphael, Gilbert Proulx, and Steven W. Buskirk, eds. Copyright © 2012 by Cornell University. Used by permission of the publisher, Cornell University Press.).

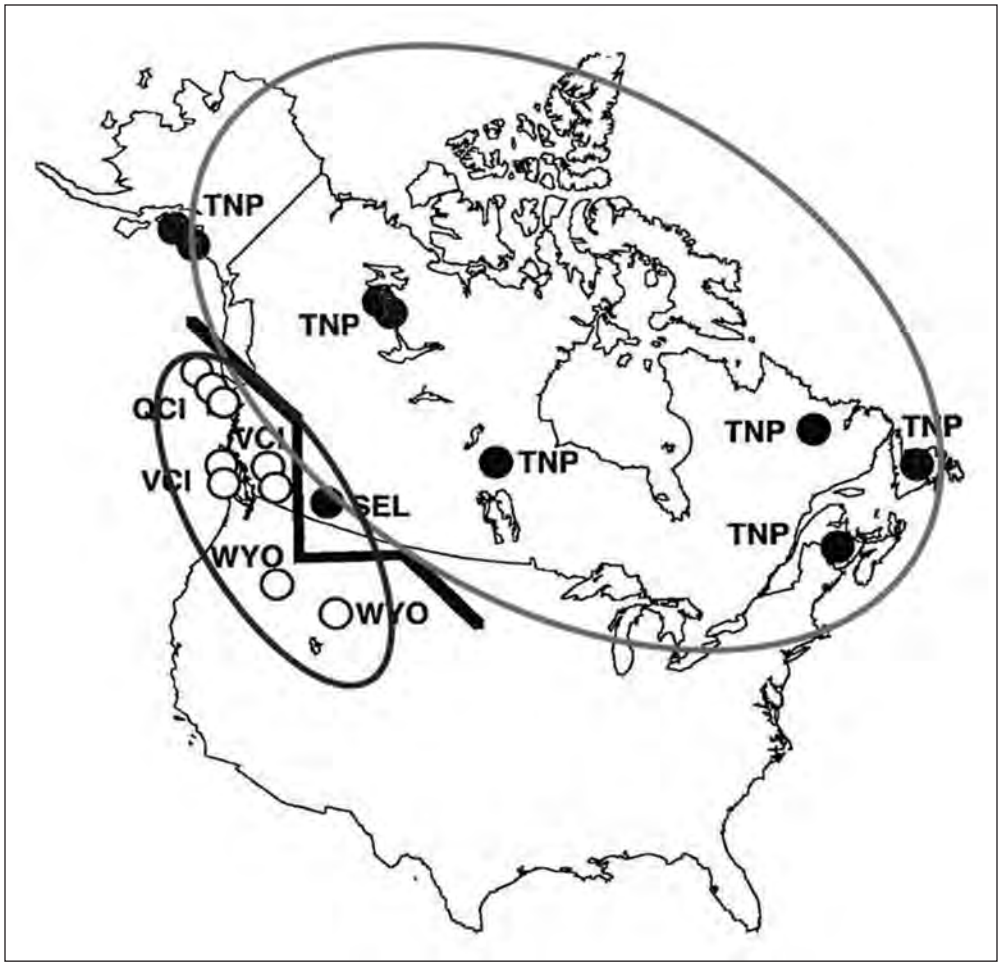


Figure 4—The geographic boundary between *Martes americana* (dark circles enclosed by light grey ellipse) and *M. caurina* (open circles enclosed by dark gray ellipse) based on cytochrome b gene sequence data. Although not depicted, the martens in California are within the new species, the Pacific marten (*M. caurina*). Illustration from Dawson and Cook (2012), adapted from Carr and Hicks (1997). Reprinted from *Biology and Conservation of Martens, Sables and Fishers: A New Synthesis*, Keith B. Aubry, William J. Zielinski, Martin G. Raphael, Gilbert Proulx, and Steven W. Buskirk, eds. Copyright © 2012 by Cornell University. Used by permission of the publisher, Cornell University Press.

**Martens are extremely sensitive to the loss and fragmentation of mature forest habitat and rarely occupy landscapes after >30 percent of the mature forest has been harvested.**

## Marten Ecology

Martens are generally associated with late-successional conifer forests (Powell et al. 2003) characterized by an abundance of large dead and downed wood, and large, decadent live trees and snags (Buskirk and Ruggiero 1994), especially in boreal and montane forests of western North American (Thompson et al. 2012). The marten distribution overlaps the fisher distribution slightly in the Sierra Nevada but extends to much higher elevation (about 1350 to 3200 m [4,500 to 10,500 ft]) red fir and lodgepole pine forests. Martens are extremely sensitive to the loss and fragmentation of mature forest habitat and rarely occupy landscapes after >30 percent of the

mature forest has been harvested (Bissonette et al. 1997, Chapin et al. 1998, Hargis et al. 1999, Potvin et al. 2000). Home ranges of Pacific martens in the Sierra Nevada average 300 to 500 ha (740 to 1235 ac) for males and 300 to 400 ha (740 to 990 ac) for females (Spencer et al. 1983). The physical structure of forests appears to be more important to marten habitat quality than plant species composition (Buskirk and Powell 1994). Martens require abundant large trees and dead-wood structures to provide prey resources, resting structures, and escape cover to avoid predators. How these elements are provisioned over space and time in a manner that permits martens to persist is unknown. However, as discussed in chapter 1.2, "Integrative Approaches: Promoting Socioecological Resilience"—and foreshadowed in PSW-GTR-220 (North et al. 2009)—restoring forests to conditions where natural disturbances can affect vegetation structure and composition may likely provide sufficient habitat for martens, fishers, and other species that have evolved with periodic disturbance, especially low-intensity fire.

In the Sierra Nevada and Cascade Range of California, martens are associated with late-successional forests dominated by true fir (*Abies* spp.) and lodgepole pine forests and are most abundant where old-growth forest characteristics are abundant (Ellis 1998, Spencer et al. 1983). Riparian zones, especially near mature forests, are important foraging areas (Martin 1987, Spencer et al. 1983, Zielinski et al. 1983). Other than this, little is known about the effect of topography on the distribution of marten habitat or marten behavior. Resting sites used by Sierra Nevada martens differ with the season. Aboveground cavities in the largest diameter trees and snags are primarily used during the summer (fig. 5), whereas subnivean logs, snags, and stumps are typically selected for resting during the winter (Martin and Barrett 1991, Spencer 1987). Martens can inhabit younger or managed forests as long as some of the structural elements found in older forests remain, particularly those required for resting and denning (Baker 1992, Porter et al. 2005, Thompson et al. 2012). On the Lassen National Forest, male martens preferentially used open shelterwood stands during the summer, when chipmunks and ground squirrels were available in these relatively open areas; however, females showed strong year-round selection of old-growth stands (uncut, large-tree stands with tree cover >69 percent) (Ellis 1998). The size of openings that martens will cross in the Sierra Nevada or Cascade Range is currently under study (see box 7.1-2 on page 420). However, in the Rocky Mountains, the average width of clearcuts (openings) crossed by martens was 140 m (460 ft); this distance is significantly less than the average width of clearcut openings that martens encountered but did not cross (average = 320 m [1,050 ft]) (Heinemeyer 2002). Moreover, martens were more likely to cross larger openings (maximum distance = 180 m [600 ft]) that had some structures in them (i.e., isolated

Mark Linnell

Figure 5—Marten in a red fir (*Abies magnifica*), Plumas County, Lassen National Forest.

trees, snags, logs) than smaller openings (average distance = 50 m [160 ft]) that had no structures (Heinemeyer 2002). Cushman et al. (2011) reported that snow-tracked martens in Wyoming strongly avoided openings and did not venture more than 17 m (55 ft) from a forest edge.

Martens are dietary generalists, although their diet changes with seasonal prey availability, and during particular seasons they may specialize on a few specific prey species (Martin 1994, Zielinski et al. 1983). The diet is dominated by mammals, but birds, insects, and fruits are seasonally important (Martin 1994). The diet of the marten in the Sierra Nevada changes with season, as does the time of day that martens search for particular prey (Martin 1987, Zielinski et al. 1983). Winter prey is primarily Douglas squirrel (*Tamiasciurus douglasii*), snowshoe hare, voles (*Microtus* sp.), and flying squirrels (*Glaucomys sabrinus*). In the summer, the diet switches to include ground-dwelling sciurids, and voles continue to be important prey (Zielinski et al. 1983). Several of the key prey species reach their highest densities in forest stands with old-growth structural features (e.g., red-backed vole

(*Clethrionomys californicus*), Hayes and Cross 1987, Zabel and Waters 1992;[3] flying squirrel, Waters and Zabel 1995; Douglas squirrel, Carey 1991).

Pacific martens typically occur in forested regions that receive considerable snowfall, and they are well adapted to these conditions. They have relatively low foot loading (i.e., high foot surface area to body mass ratio), which allows them to move relatively easily over deep, soft snow, and they are adept at using subnivean environments for foraging and resting. This gives martens a competitive advantage over larger carnivores that may otherwise compete with or prey on martens, such as bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and fishers, whose distributions are limited by deep, soft snow (Krohn et al. 1997, 2004).

## Fisher Ecology

In western North America, fishers are associated with late-successional conifer or mixed-conifer-hardwood forests characterized by an abundance of dead and downed wood, dense canopy, and large trees (Buskirk and Powell 1994, Lofroth et al. 2010, Purcell et al. 2009, Raley et al. 2012, Zielinski et al. 2004a). Fishers occur in a variety of low and mid-elevation forests (primarily the ponderosa pine and mixed-conifer types) where canopy is moderate to dense, but the vegetation types constituting the home range can be heterogeneous (Lofroth et al. 2010, Thompson et al. 2011). In the Sierra Nevada, fishers occur primarily in mixed-conifer and ponderosa pine forests from 1065 to 2030 m (3,500 to 7,000 ft), elevations that do not typically receive deep and persistent snow, which is thought to restrict their movements (Krohn et al. 1995, 1997). Powell and Zielinski (1994) hypothesized that forest structure was more important than tree species for fisher habitat. Complex structure, including a diversity of tree sizes, snags, downed trees and limbs, and understory vegetation, provides den and rest sites and hiding cover for fishers, as well as habitat for their prey. Both inactive (resting and denning) and active (foraging) fishers are typically associated with complex forest structure (Lofroth et al. 2010, Zhao et al. 2012).

Fishers forage in a manner that suggests that they use habitat at four scales: the resting site, the stand, the home range, and the landscape. Resting and denning (i.e., parturition and neonatal care) typically occur in trees, snags, and logs that are in the largest diameter classes (Aubry et al. 2012, Lofroth et al. 2010, Raley et al. 2012) and are either deformed or in some form of decay (Weir et al. 2012). For example,

[3] Zabel, C.J.; Waters, J.R. 1992. Associations between forest structure and abundances of flying squirrels and other small mammals. 12 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Arcata, CA 95521.

the average diameters at breast height (dbh) of conifer and hardwood rest trees in one study in the Sierra Nevada were 109 and 66 cm (43 and 26 in), respectively (Zielinski et al. 2004a). In an innovative new study using LiDAR to characterize the vegetation structure surrounding den trees, Zhao et al. (2012) found that tree height and slope were important variables in classifying the area immediately surrounding denning trees. At scales larger than 20 m (65 ft), forest structure and complexity became more important. The variables identified using LiDAR were consistent with those identified from previous studies describing fisher resting structures.

**The strong association of fishers with dense forest stands that contain a diversity of tree sizes complicates the ability of management activities to achieve what seem like mutually exclusive goals: the reduction of stand densities and fuels, and the maintenance of fisher habitat.**

The strong association of fishers with dense forest stands that contain a diversity of tree sizes complicates the ability of management activities to achieve what seem like mutually exclusive goals: the reduction of stand densities and fuels, and the maintenance of fisher habitat. The basal area of small-diameter trees is an important predictor of fisher resting sites (Zielinski et al. 2004a). The smaller trees may provide the requisite canopy cover needed by fishers, as long as a suitably large resting structure (tree or snag) is also available (Purcell et al. 2009). Some researchers have speculated that the dense forest conditions that appear attractive to fishers today may be an artifact of past logging practices and fire suppression. These factors may have changed forest conditions from stands dominated by large trees and snags to dense stands with size class distributions that included more small-diameter trees (Collins et al. 2011, Scholl and Taylor 2010). Topography affects the distribution of dense forests and the effect of fire severity (North et al. 2009), as well as the distribution of fisher resting sites. Underwood et al. (2010) found that fisher activity locations were disproportionately found in lower topographic positions (i.e., canyons), as well as in southerly and northerly mid-slope positions.

As generalized predators, fishers prey on a variety of small and medium-sized mammals and birds, and they also feed on carrion (Martin 1994, Powell 1993). In California, reptiles and insects are also notable components of the diet (Golightly et al. 2006, Zielinski et al. 1999). Home range size appears to be a function of the abundance of food, in that fishers whose diet includes a significant component of relatively large (>200 g) food items (e.g., woodrat [*Neotoma* sp.] and western gray squirrel [*Sciurus griseus*]) have significantly smaller home ranges (Slauson and Thompson[4] ).

[4] Slauson, K. 2013. Unpublished data from fisher diet and home range study. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Dr., Arcata, CA 95521.

Thompson, C. 2013. Unpublished data from fire effects on fisher study. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2081 E Sierra Ave., Fresno, CA 93710.

Predation is probably the predominant cause of death, and fishers are regularly killed by cougars (*Puma concolor*), coyotes, and bobcats (Lofroth et al. 2010). Fishers are also affected by viral and parasitic diseases, such as canine distemper, parvovirus, and toxoplasmosis, and they are victims of poison distributed to control rodents (Brown et al. 2006; Gabriel et al. 2012a, 2012b).

## Population Status

### Marten Populations

Martens were legally trapped for fur in California until 1954, and the earliest summary of the trapping records indicated that the marten was well distributed across its native range in the early 1900s (Grinnell et al. 1937). However, declining numbers resulting from intense trapping pressure during this period resulted in the prohibition of trapping. Before and during this period, California's primary forests were heavily harvested (Bolsinger and Waddell 1993, Franklin and Fites-Kaufmann 1996, McKelvey and Johnston 1992), adding to the pressure on marten populations.

Recent research has focused on the distributional dynamics of the marten in the Sierra Nevada and Cascade Range. Concern about the decreasing distribution of martens in some regions of the Pacific States has been voiced for decades (Dixon 1925, Kucera et al. 1995, Zielinski et al. 2001). Historical and contemporary distributions in the Sierra Nevada and Cascade Range were compared by contrasting the locations of animals trapped for their fur in the early 1900s (Grinnell et al. 1937) with surveys recently conducted (Zielinski et al. 2005) using noninvasive methods (track stations and cameras) (Long et al. 2008). These surveys revealed changes in the distributions of a number of carnivore species, including the marten, fisher, wolverine, and Sierra Nevada red fox. Historically, the marten was reported to occur throughout the upper montane regions of the Cascade Range and northern Sierra Nevada, but survey results indicate that populations are now reduced in distribution and fragmented (Zielinski et al. 2005).

Change in habitat distribution in the Cascade Range and northern Sierra Nevada has also been demonstrated using predictive habitat modeling. The results of surveys were used to build landscape habitat suitability models by contrasting the environmental features at places where martens were detected with the features at places where they were not. This work confirmed that the available habitat for martens is isolated and has been reduced in area since the early 1900s (Kirk and Zielinski 2009). The model that best fit the data suggested that remaining marten populations are associated with sites with the largest amount of reproductive habitat (dense, old forest), the greatest number of nearby habitat patches, and nearby reserved land (land protected from timber harvest). The highest density

of detections was located in the largest protected area in the study region: Lassen Volcanic National Park. This is in stark contrast to descriptions of historical distribution, which described martens as evenly distributed in the region during the early 1900s, including at lower elevation sites (Grinnell et al. 1937, Zielinski et al. 2005).

The loss of marten distribution seems clear, but what is less clear is the cause. This is difficult to ascertain with data from such a large region; what is necessary instead is a more focused effort to contrast areas that have maintained their marten populations compared to those that have not. Recent work in the Sagehen Experimental Forest (SEF), within the Sagehen Creek watershed on the Tahoe National Forest, may be helpful in this regard (Moriarty et al. 2011). The watershed has been the location for a number of studies on marten ecology in California, but the unique element of this body of work is that most of these studies also included a systematic survey of marten occurrence. Martens were assumed to be very common in the watershed in the 1970s and 1980s, but anecdotal observations have suggested that they subsequently became quite rare. This concern led to new surveys in 2007 and 2008, which detected no martens during summer surveys (June through September), despite the fact that martens were regularly detected during the summer in earlier surveys (Moriarty et al. 2011). A few marten detections occurred in the winter, but these were in a small western portion of the watershed. Marten detections in 2007 and 2008 were approximately 60 percent fewer than in surveys in the 1980s. Thus, at the scale of the Sagehen Creek watershed, the same phenomenon was observed that was described for the northern Sierra Nevada/southern Cascade Range as a whole (Zielinski et al. 2005).

The cause of the decrease in marten numbers at Sagehen is uncertain. However, geographic information system analysis comparing older vegetation maps from 1978 with maps from 2007 revealed a loss and fragmentation of important marten habitat (Moriarty et al. 2011). This included a decrease in habitat patch size, core habitat area, and total amount of marten habitat in the study area, as well as an increase in distance between important habitat patches. For example, the mean area of patches of reproductive habitat decreased from 56.6 ha to 44.5 ha, and the mean distance between these patches increased from 194 to 240 m over the almost 30-year period (Moriarty et al. 2011). Many of these changes occurred between 1983 and 1990, when 39 percent of the forest habitat in SEF experienced some form of timber harvest (i.e., regeneration, selection, hazard tree removal). The sensitivity of martens to forest fragmentation is well established (e.g., Bissonette et al. 1989, Hargis et al. 1999, Potvin et al. 2000). Given this, and the fact that the loss of martens at Sagehen coincided with the period of greatest harvest activity in the

study area, the loss and fragmentation of habitat is the most likely explanation for the decline at SEF (Moriarty et al. 2011). Collectively, the evidence from studies at Sagehen, and from the larger Cascade Range and northern Sierra Nevada region, supports the conclusion that the distribution of martens in this region has decreased. On the contrary, however, evidence from surveys in the central and southern Sierra Nevada (Kucera et al. 1995, Zielinski et al. 2005) suggests that the marten population is well distributed.

**Collectively, the evidence from studies at Sagehen, and from the larger Cascade Range and northern Sierra Nevada region, supports the conclusion that the distribution of martens in this region has decreased.**

## Fisher Populations

Following European settlement of North America, fisher range contracted drastically, particularly in the southern regions, because of deforestation and trapping (Powell 1993). In California, Grinnell et al. (1937) described the original range of the fisher as including the northern Coast Range, Klamath Mountains, southern Cascade Range, and the entire western slope of the Sierra Nevada. The status of the fisher in California has been of concern for almost 100 years, beginning with Dixon (1925), who believed that the fisher was close to extinction in California and proposed that protective measures be taken. Consequently, trapping of fishers in California was prohibited in 1946—considerably later than was suggested by Dixon (1925). Population decline and fragmentation have reduced genetic diversity in California, particularly in the southern Sierra Nevada (Drew et al. 2003, Tucker et al. 2012, Wisely et al. 2004), and the two native fisher populations in California are geographically and genetically isolated (Knaus et al. 2011, Tucker et al. 2012, Wisely et al. 2004, Zielinski et al. 1995). Due, in part, to the genetic and population data available at the time, the U.S. Fish and Wildlife Service determined that the West Coast Distinct Population Segment (as defined by the Endangered Species Act [ESA]) in California, Oregon, and Washington was "warranted but precluded" for listing under the ESA (U.S. Federal Register, April 8, 2004).

Survey data indicate that fishers currently occur in two widely separated regions of the state: the northwest, including the northern Coast Range and Klamath Province, and the southern Sierra Nevada (Aubry and Lewis 2003, Zielinski et al. 1995). This creates a gap in their distribution of approximately 400 km (250 mi) in the northern Sierra Nevada and southern Cascade Range, which has previously been attributed to the historical effects of trapping and timber harvest (Zielinski et al. 1995, 2005). Contrary to the conclusions of Grinnell et al. (1937)—and an earlier report suggesting fishers were trapped in the gap region in the early 1900s (Grinnell et al. 1930)—new genetic analysis suggests that the two populations in California were separated prior to European influence in the region (Knaus et al. 2011, Tucker et al. 2012). Further study of this genetic information is pending (see box 7.1-2),

but this new genetic information does not necessarily mean that fishers did not once occupy most of the Sierra Nevada and southern Cascade Range. Depending on one's view of the size of the historical gap between fisher populations in the Sierra Nevada, the fisher currently occupies anywhere from 20 to 90 percent of its historical range in California. If the gap predates European influence and was as large then as it is today, the current range of fishers in California would be about 90 percent of the pre-European historical range. If the gap was as small as a few fisher home ranges wide, then the current range may be no more than 20 percent of the historical range. In 2009, a small population of fishers was reintroduced to Butte and Tehama Counties (Facka and Powell 2010) within the presumed gap in the distribution; results from this reintroduction are pending (see box 7.1-2), and it is too soon to evaluate the contribution these animals will make to fisher populations in California.

The distribution of the fisher population in the southern Sierra Nevada has been monitored since 2002, and there has been no change in the proportion of detection stations with a fisher detection (i.e., occupancy); the population appears stable (Zielinski et al. 2012). Based on habitat and population modeling, the size of the southern Sierra Nevada population has been estimated to be between 125 and 250 adults (Spencer et al. 2011). This is consistent with an estimate extrapolated from fisher density calculated by Jordan (2007) from a mark-recapture study.

## Threats to the Species and Implications for Management

### Marten—Threats

**Timber harvest, vegetation management, and wildfire—**
Timber harvest and fur trapping are regarded as the primary causes of reductions in marten populations in the Western United States (Buskirk and Ruggiero 1994). Commercial fur trapping is the most direct way that humans have affected marten populations, but California prohibited marten trapping in 1954. Current threats include the continuing effects of habitat loss and fragmentation from timber harvest, particularly clearcutting, and vegetation management to reduce fuels. Wildfire is a serious threat, as well, especially if wildfire size and severity are exacerbated by climate change; these issues are discussed in a separate section below, entitled "Climate Change Implications—Marten and Fisher."

Given the current rarity of clearcutting on public lands in California, the largest potential direct threat from human activities is the effect of forest thinning. Abundant literature notes the sensitivity of martens to the effects of forest fragmentation (Bissonette et al. 1997, Chapin et al. 1998, Hargis et al. 1999, Potvin et al. 2000),

but in these cases, the fragmentation is typically due to regeneration or clearcut harvests. How thinning treatments fragment habitat is poorly known, but it is under study in the Cascade Range in California (see box 7.1-2). Although we have little local information on the effects of thinning on martens, Fuller and Harrison (2005) evaluated how partial harvests affect martens in Maine and summarized the few data on this subject that predated their study. Partial harvests (also referred to as "partial overstory removal" in the Eastern United States) leave residual forest cover in harvest blocks. In Fuller and Harrison's (2005) study area, 52 to 59 percent of the basal area was removed in partial harvests. In these conditions, martens used the partial harvest stands primarily during the summer. When they were using partial harvest stands, their home ranges were larger, indicating poorer habitat quality in these areas. Partial harvested areas were avoided during the winter, presumably because they provided less overhead cover and protection from predators. How this work relates to predicting the effects of thinning in marten habitat in the Sierra Nevada is unclear, but the most conservative generalization would suggest that martens would associate with the densest residual areas in thinned units and may also increase their home ranges, which may lead to decreased population density. The negative effects of thinning probably result from reducing overhead cover. Thinnings from below, which retain overstory cover, probably have the least impact on marten habitat, provided they retain sufficient ground cover. Downed woody debris provides important foraging habitat for martens. Andruskiw et al. (2008) found that physical complexity on or near the forest floor, which is typically provided by coarse woody debris, is directly related to predation success for martens; when this complexity is reduced by timber harvest (a combination of clearcut and selection harvests with subsequent site preparation in their study area), predation success declines. Marten home ranges in uncut forests had 30 percent more coarse woody debris (>10 cm diameter) from all decay classes combined than in cut forests (Andruskiw et al. 2008). Retaining sufficient understory vegetation and downed wood, which are necessary marten habitat elements, will be a challenge in applying fuels treatments that are meant to reduce the density of surface fuels.

**Retaining sufficient understory vegetation and downed wood, which are necessary marten habitat elements, will be a challenge in applying fuels treatments that are meant to reduce the density of surface fuels.**

Recent genetic work in Ontario finds that forests managed for commercial value (via clearcutting) appear to be sufficiently connected to maintain gene flow, at least at the level of the province (Koen et al. 2012). This would also appear to be the case in landscapes like those planned for the Sierra Nevada forests, where thinning is the dominant silvicultural treatment, because the impact on canopy is much less. Thus, it appears possible for gene flow to be maintained in commercial forests, even when forest fragmentation reduces the abundance or distribution of martens. Commercial harvest and thinning both occurred in the Pacific Southwest Research Station's

(PSW) Sagehen Experimental Forest (Tahoe National Forest) in the last 30 years, and their cumulative effect on habitat loss was the most likely cause for the marten decline reported there (Moriarty et al. 2011). Similarly, shelterwood harvests in the red fir zone of PSW's Swain Mountain Experimental Forest (Lassen National Forest) led to open conditions (i.e., percentage of canopy cover from largest size class trees = 10 to 19 percent) that were used less often by martens during the winter (Ellis 1998). Thus, clearcutting, and partial cutting and thinning, have been reported to have negative effects on populations, though they may not necessarily have deleterious effects on gene flow.

**Recreation—**

Recreation has the potential for significant impacts to marten populations, especially winter recreation that occurs in high-elevation montane forests or subalpine zones. The sound of engines from off-highway vehicles (OHVs) may disturb marten behavior directly, but in winter, the use of snowmobiles can also have indirect effects by compacting the snow, which permits access to marten areas by competing carnivores that would not typically be able to traverse deep snow (Buskirk et al. 2000). The only study to explore the effects of OHVs on martens in the Sierra Nevada found that marten occupancy at two study areas was unaffected by year-round OHV use (Zielinski et al. 2008). Martens were ubiquitous in both control and OHV use areas, and there was no effect of use areas on probability of detection, nor were martens more nocturnal in the OHV use areas than the control areas. Moreover, females were not less common in the OHV use areas compared to the controls. However, martens were exposed to relatively low levels of disturbance overall, and most OHV use occurred at a time of day when martens were inactive (Zielinski et al. 2008).

Ski resorts are considered likely to affect marten populations because they remove and fragment high-elevation fir forest habitat. There are about 25 ski resorts in the Sierra Nevada, and nearly all occur within the range of the marten. The Lake Tahoe region includes approximately half of these resorts, constituting the highest density of resorts in the Sierra Nevada and one of the highest in North America. To create ski runs, chair lifts, and associated facilities, trees are removed, creating open areas and fragmenting forest. Martens typically avoid open areas that lack overhead cover or tree boles that provide vertical escape routes from predators (Drew 1995), are more susceptible to predation if they must cross such areas, and have been shown to avoid areas when >30 percent of mature forest has been removed (Bissonette et al. 1997). Snow compaction from grooming alters surface

consistency, making it easier for larger bodied carnivores (e.g., coyotes)—which, unlike martens, are not adapted for deep, soft snow—to expand their winter ranges and compete with or prey on martens (Bunnell et al. 2006, Buskirk et al. 2000). Skiers and staff are active during most of the day, and grooming and some skiing activity occur at night. Thus, martens that are sensitive to these activities may not find time for important foraging activities. Ski resort effects are not limited to winter, as habitat fragmentation is a year-round effect and many resorts are developing summer recreational activities (e.g., hiking, mountain biking).

Kucera (2004) conducted the only intensive study of martens in a ski area in California. He captured 12 individuals at the Mammoth Mountain ski area, 10 of which were males, 1 was female, and 1 was of unknown sex, resulting in a highly skewed sex ratio. The single female raised two kits but did not use developed areas and used only natural rest sites. Martens appeared to move away from the ski area and into unmanaged forest after winter. Kucera (2004) suggested that this fits a seasonal use pattern where martens occupy ski areas during winter when natural prey is least available and human-supplied food is most plentiful, then they move into unmanaged forests in spring. This migration would allow them to exploit artificial food sources during winter but return to places where females maintain home ranges to breed in summer. Realizing that this study required confirmation and a larger sample, Slauson and Zielinski (see box 7.1-2) began a 4-year study in 2008 to evaluate the effects of ski area development and use on home range and demography of marten populations. Field work is completed and a final report is pending.

**Roads, predation, and other mortality—**

Roads represent a direct threat to martens (via road kill), as well as an indirect threat by facilitating an increase in the interactions between martens and their predators and competitors (Slauson et al. 2010). Martens are susceptible to predation by coyote, red fox, bobcat, and great horned owl (*Bubo virginianus*) (Bull and Heater 2001, Lindström et al. 1995, Thompson 1994). Marten populations in highly altered forest landscapes (i.e., dominated by landscapes fragmented by regeneration and partial harvests and roads) show higher rates of predation and lower annual survival rates than those in less altered forest landscapes (Belant 2007, Bull and Heater 2001, Thompson 1994). The mechanism for these demographic effects is presumably linked to the risk of predation incurred by martens when they use stands with less cover or, for example, when fragmented habitat requires martens to use additional energy to travel through their home ranges using only the patches of residual stands. Use of rodenticides, particularly at illegal marijuana cultivation sites on public and private lands, is also a potential threat (Gabriel et al. 2012b).

## Management Implications—Marten

**It makes sense that treating forests to reduce the severity of fire be conducted in proportion to the expectation of catastrophic fires and priorities for restoration.** Fortunately, fire return intervals in the true fir and subalpine zones, where martens are most common, are not as short as in the mid-elevation forest types (mean maximum fire return interval in red fir = 130 years; Van de Water and Safford 2011), so red fir forests are not a high priority for restoration treatments, especially given the backlog of treatments in more fire-prone forest types. Thus, it would appear that **there is less impetus for land managers to thin canopies and reduce surface fuels—both actions that potentially reduce habitat quality for martens—in true fir forests than in the mixed-conifer forests at lower elevations. Although there may be a need for restoration treatments in the high-elevation forests, this should be initiated based on strategic fire planning that accounts for the habitat needs of martens at multiple scales** (i.e., landscape connectivity, home range quality, and the provision of microhabitat elements).

Long-term viability for martens will most likely require evaluating habitat connectivity and restoring it where is it is found to be lacking. This is challenging for a number of reasons: (1) there are few studies evaluating the viability of martens under alternative forest management regimes (e.g., Carroll 2007, Fuller and Harrison 2005, Lacey and Clark 1993), and none in California; and (2) fragmented marten habitat is at additional risk from a warming climate because it occurs near the upper elevational range of forests (Carroll 2007, Lawler et al. 2012, Purcell et al. 2012). Thus, if maintaining adequate marten habitat is desired, plans could be made for connectivity of upper montane forest stands that may migrate to higher elevations in the future. The California Essential Habitat Connectivity Project (Spencer et al. 2010) may be of some value in this regard, but it is a coarse-scale project of statewide scope. Guidelines for developing connectivity maps at finer resolution are available (e.g., Beier et al. 2011, Spencer et al. 2010), and some work of this nature has been conducted in the vicinity of Lassen National Forest to evaluate the effects of projects on connectivity (Kirk and Zielinski 2010). Furthermore, predicting marten habitat connectivity along the length of the Sierra Nevada and Cascade Range in California is underway (see box 7.1-2). Also noteworthy is the recent effort to reestablish fishers in the northern Sierra Nevada (Facka and Powell 2010); the implications of the growth of this new fisher population on martens in the California Cascades should be explored.

The Sierra Nevada Framework (USDA FS 2001, 2004) specifies a marten monitoring program on Forest Service lands. Periodically, over the 10-year duration of the fisher monitoring program (Zielinski and Mori 2001, Zielinski et al. 2012),

some sample units at sufficiently high elevation have detected martens, but martens have not been the target of a species-specific program, nor have the data from the fisher monitoring program been analyzed for their value in monitoring change in occupancy of the Sierra marten population. A marten-specific monitoring program would produce benefits to managers similar to the occupancy monitoring program for fishers in the southern Sierra Nevada.

## Fisher—Threats

**Timber harvest, vegetation management, and wildfire—**
Fishers are sensitive to loss of late-successional habitat via timber harvest and vegetation management and to loss of habitat by uncharacteristically severe fire. Weir and Corbould (2010), studying fishers in British Columbia, found that a 5-percent increase in clearcut logging (equivalent to 240 ha [590 ac] of a 4775 ha [11,800 ac] study area, over 12 years) decreased the probability of home range occupancy by 50 percent. This is probably because fishers avoid establishing home ranges in areas with a high density of openings (Weir and Corbould 2010). Resting and denning structures are probably the most limiting habitat element (Powell and Zielinski 1994, Purcell et al. 2012). Because fishers move between rest sites on a daily basis, and reuse is low (Lofroth et al. 2010), suitable resting structures need to be numerous and well distributed throughout home ranges. Fishers prefer to rest in shade-intolerant trees, such as black oaks and ponderosa pines (Purcell et al. 2009), which, due to selective harvest and fire suppression, are now less abundant than they were historically (Collins et al. 2011, McDonald 1990, Roy and Vankat 1999, Scholl and Taylor 2010). However, white fir, which is more abundant than it was historically, is also frequently used for resting sites in the Sierra Nevada (Purcell et al. 2009, Zielinski et al. 2004a). Thus, any management actions or disturbance factors (e.g., logging of large-diameter trees, high-severity fire) that further reduce the abundance of large conifers (>76 cm [30 in] dbh), particularly ponderosa pines, sugar pines and white fir, as well as black oaks, will negatively affect fishers. Therefore, a long-term strategy for the regeneration and growth of black oak and ponderosa pine (the two most shade-intolerant species that fishers use as resting sites) will probably be an important conservation action for fishers. This will require reducing the density of species that have benefited from fire suppression (e.g., incense cedar and white fir), as specified by North et al. (2009), especially trees that are in the smaller size classes (particularly <50 cm [20 in] dbh). Because fishers, martens, and other species, however, will rest in the cavities in the larger white fir, and we do not know the minimum number of cavities to maintain habitat for these species, a conservative approach would call for retaining white fir trees in the largest size classes.

**Treatments to reduce fire severity can be beneficial if they do not reduce the density of important habitat elements, such as the largest size classes of trees, snags, and logs, or affect canopy cover on topographic positions where it is naturally dense, typically on north- and east-facing slopes.**

Naney et al. (2012) summarized the significant threats to fishers for each bioregion within the fisher's range in the Pacific states and provinces. In the Sierra Nevada, the highest threats were determined to be severe wildfire and fire suppression activities, fuels reduction and timber harvest, and fragmentation. A tradeoff exists between the loss of habitat value that occurs when forests are thinned to reduce the severity of future fires and the loss of habitat that occurs when untreated stands are consumed by wildfire. Treatments to reduce fire severity can be beneficial if they do not reduce the density of important habitat elements, such as the largest size classes of trees, snags, and logs, or affect canopy cover on topographic positions where it is naturally dense, typically on north- and east-facing slopes (North et al. 2009). The definition of "large" is important, because managers frequently request threshold values. Subtracting one standard deviation from the mean dbh of fisher resting sites could be a reasonable, and conservative, threshold for the interpretation of "large" trees. Using this assumption, "large" live conifers and snags would be those that exceed 63.5 and 71 cm (25 and 28 in) dbh, respectively (data from Purcell et al. 2009).

Simulation studies have revealed that carefully applied treatments (thinning from below and the treatment of surface fuels) within fisher habitat may be more effective at reducing the loss of habitat than when treatments are placed outside such habitat (Scheller et al. 2011). Unlike the California spotted owl (*Strix occidentalis occidentalis*), for which the response to fuel treatments has been explored both empirically and via modeling (e.g., Lehmkuhl et al. 2007, Roberts et al. 2011), there is no published work to evaluate the direct effects of fuels treatment (mechanical or prescribed fire) on fishers. A recent study, however, evaluated the effects of various treatment types on predicted values of fisher resting habitat (Truex and Zielinski 2013). The effects of actual treatments were compared by evaluating their effects on predicted fisher habitat based on fisher habitat models developed in the southern Sierra Nevada. The effects of mechanical thinning, prescribed fire, and the combination of mechanical thinning and prescribed fire were compared to controls at the University of California–Berkeley's Blodgett Forest Research Station in the central Sierra Nevada. The combination of thining and fire had significant short-term impacts on predicted fisher resting habitat quality, as well as on canopy closure, a key habitat element for fisher in California. Early (June) and late season (September and October) prescribed fire treatments were compared at Sequoia-Kings Canyon National Parks. The late-season burn treatment had a significant negative impact on modeled fisher habitat suitability when measured 1 year later (Truex and Zielinski 2013). Although predicted resting habitat suitability was significantly reduced by some treatments, there were no negative effects on predicted foraging habitat. Although the treatments that included mechanical methods had greater short-term reduction on modeled fisher resting habitat suitability than prescribed fire, these effects were mitigated by the fact that mechanical

treatments could target or avoid individual trees. Hardwoods and all large trees and snags could more easily be avoided using mechanical means of treatment. Furthermore, even the use of fire could be controlled somewhat by raking debris from the base of particular trees that were viewed as important to protect. Thus, it appears that if care is taken to apply treatments with the goal of protecting large hardwoods and conifers, and there are funds to conduct the raking, the potential reduction in predicted habitat quality may be mitigated (Truex and Zielinski 2013). Long-term strategies that encourage the regeneration, and growth to large size, of black oaks, ponderosa pines, and white fir will also be an important conservation action (e.g., North et al. 2009). Some white fir may need to be removed to encourage the development of oaks and pines, but cavities in large white fir are used as resting sites by fishers and martens. The large white fir may need to be retained during the transition to forests that eventually produce pines and oaks of cavity-bearing size, particularly for fishers. However, martens use large white fir at an elevation above where black oaks and ponderosa pines occur, so the maintenance of an abundant supply of large white fir in the upper montane zone will be an important component of marten habitat management.

**Management to reduce fire risk, or to restore ecological resilience to fire, may be consistent with the maintenance of landscapes capable of supporting fishers, as long as sufficient resting/denning structures are retained and the composition and configuration of the residual landscape is compatible with home range requirements.**

Studies on spotted owls suggest that the use of prescribed fire to reduce the density of small trees can be compatible with owl occupancy (Ager et al. 2007, Lehmkuhl et al. 2007, Roberts et al. 2011, Roloff et al. 2012). Some of this research predicts, via modeling, that fuels treatments on a relatively small proportion of the forest landscape result in significant decrease in the probability of owl habitat loss following wildfire (e.g., Ager et al. 2007). If this work also applies to fishers, it suggests that in fire-suppressed forests, a "no action" management option may involve greater risk to fishers than some form of treatment because these ecosystems have diverged from historical (and also more resilient) conditions (Purcell et al. 2012, Thompson et al. 2011). Management to reduce fire risk, or to restore ecological resilience to fire, may be consistent with the maintenance of landscapes capable of supporting fishers, as long as sufficient resting/denning structures are retained and the composition and configuration of the residual landscape is compatible with home range requirements (e.g., Thompson et al. 2011).

Because prescribed fire can pose a threat to fisher habitat, early-season burns appear to be preferable to late-season burns (Truex and Zielinski 2013). Early burns, which are timed to follow the fisher denning period in spring, will minimize the likelihood of disturbing denning female fishers. If conditions necessitate burning earlier than mid-May, efforts could be made to avoid treating areas that have a high density of structures likely to be used by females for denning (for reference to denning structures and denning habitat, see Lofroth et al. 2010 and Thompson et al. 2010, and box 7.1-2).

**Box 7.1-1**

### Pending Research on Fisher Resting Habitat

A recent meta-analysis of fisher resting habitat studies throughout the Western United States and Canada provides some overarching conclusions about the features that distinguish resting sites from random forest sites (Aubry et al. 2013). This work includes the results of five studies in California and reinforces the conclusions of those independent studies in terms of the importance of retaining large trees, snags, and logs and dense cover for fisher resting habitat. The authors found that resting sites differed from random points at all eight study areas in the following respects: resting sites had steeper slopes, lower heat load indices, higher overhead cover, greater volume of logs ≥26 cm in mean diameter, greater basal area of large (51 to 100 cm diameter at breast height [dbh]) conifers, greater basal area of large hardwoods, greater basal area of large snags, larger mean dbh of live conifers ≥10 cm dbh, and larger mean dbh of live hardwoods ≥10 cm dbh. Reductions in the values for these features should be considered threats to the availability of resting habitat for fishers in the Sierra Nevada, and elsewhere in the fisher's western range.

**Roads, predation, and other mortality—**
Because of their delayed maturation and the fact that not all females reproduce each year, fisher population growth rates are relatively low (Lofroth et al. 2010). Thus, the recently reported high rates of predation on fishers (Thompson et al. 2010; see box 7.1-2), especially by bobcats and cougars, are of concern. Fisher mortality associated with roads is another important concern (see box 7.1-2). Use of rodenticides, particularly at illegal marijuana cultivation sites on public lands, is also a growing threat (Gabriel et al. 2012b). Fishers are also affected by viral and parasitic diseases (Brown et al. 2006, Gabriel et al. 2012a), but the magnitude of the direct and indirect effects of these organisms on fisher populations is unknown.

## Management Implications—Fisher

Recent research findings (summarized in Purcell et al. 2012) support the validity of previous recommendations to **focus habitat management for fishers in areas where, historically, fires would have burned less frequently, such as north and east-facing slopes, canyon bottoms, and riparian areas** (North et al. 2009). Resting sites are often found close to streams and on relatively steep slopes (Purcell et al. 2009, Zielinski et al. 2004a), and fisher telemetry locations include more observations in canyons and fewer observations on ridges (Underwood et al. 2010). These are landscape-scale recommendations, but as noted earlier in this review, home range and stand-scale level recommendations frequently center on

protecting large-diameter hardwoods and conifers (but not specifying how many per acre are necessary) and maintaining canopy cover (e.g., a minimum of 56 to 61 percent canopy cover in stands, depending on the method of measurement; Purcell et al. 2009). Stand- and home range-scale management is often more problematic because areas used are not homogeneous, and no single threshold should be applied to all stands or home ranges. This is why a landscape-scale approach to management of forests in the Sierra Nevada would help ensure adequate fisher habitat. **Not all stands need to meet the minimum standard for occupancy, but for occupancy to occur in a home-range-sized area, there is a typical collection of composition and configuration attributes that are derived from stand-level information (e.g., Thompson et al. 2011). A process-based approach to generating heterogeneity in landscape condition, like that offered in PSW-GTR-220 (North et al. 2009), will not only be superior to a stand-by-stand level approach, but may be the only approach possible given the logistical challenges of describing stand-level variables and the difficulty of recording and tracking the changes in stand-level conditions in large areas over space and time.**

The approach recommended in North et al. (2009) also encouraged the retention of oaks and pines, and stressed the importance of hardwoods, especially California black oaks (*Quercus kelloggii*). Black oaks require openings for regeneration and subsequent growth (McDonald 1990), suggesting that **the creation of small openings around mature productive trees would aid establishment of young trees needed to replace dying oaks. It would be best to balance this approach with retaining smaller trees around oaks with visible cavities that are currently suitable as resting or denning structures.** Most oaks used by fishers are live trees, although dead portions (e.g., broken limbs with access to cavities) of otherwise healthy trees are important (Purcell et al. 2009, Zielinski et al. 2004a).

**Monitoring of fisher habitat and populations is an essential component of adaptive management.** Fortunately, a number of research and management efforts have established the groundwork for these components. **There now exist empirical models that can be used to assess and monitor fisher habitat at the resting site, home range, and landscape scales for various locations in the Sierra Nevada.** The effects of forest practices on fisher resting habitat can be quantitatively evaluated with the development of a model for the southern Sierra Nevada that predicts resting habitat value from plot data (Zielinski et al. 2006, 2010). The model is specifically developed to use Forest Inventory and Analysis data, but can use other types of plot data, as well. This model has also been integrated with the Forest Vegetation Simulator to forecast future effects of proposed activities on fisher resting habitat (Zielinski et al. 2010). A number of regional landscape suitability models

are also available (Davis et al. 2007, Spencer et al. 2011), and they can be used for assessment and monitoring of large-scale habitat distribution and connectivity. The California Essential Habitat Connectivity Project (Spencer et al. 2010) may be of some value in this regard, but it is a coarse-scale project of statewide scope. Guidelines are now available for the development of finer scale connectivity maps (e.g., Beier et al. 2011, Spencer et al. 2010). Using these practices, a new effort is underway to model fisher habitat connectivity and to specify linkages in the central and southern Sierra Nevada (Spencer and Rustigian-Romsos 2012).

A specific research need identified in North et al. (2009) entailed examination of potential outcomes of proposed forest treatments based on modeling habitat in female fisher home ranges. This shortcoming has been partially addressed through the recent development of an analytical tool that predicts the relative impacts of management actions on fisher habitat in the vicinity of the Sierra National Forest (Thompson et al. 2011). This approach is a form of ecological risk management and is based on quantifying the range of variation in currently occupied female fisher home ranges. It assumes that if we manage landscapes to resemble those occupied home ranges, there is a high likelihood that the landscape will remain functional fisher habitat and minimize the risk of negative population impacts. Results in the Sierra National Forest study area indicate that female fishers use landscapes with relatively high proportions of large trees and snags, and where patches of high-quality habitat are connected in a heterogeneous mix of forest ages and conditions. Unfortunately, it is not known what size these patches must be nor how far apart they can be to assure that they become incorporated into a fisher home range. However, Thompson et al. (2011) specify the average values for female fisher home ranges in respect to a number of variables, including canopy closure, basal area, and a number of common indices of patch size and connectivity (see table 2 in Thompson et al. 2011). Values for these variables suggest the importance of variation in canopy cover and tree size values among stands within home ranges. These values, however, apply only to the region where the model was developed, but the **results suggest that some level of management to reduce fire risk may be consistent with maintaining fisher habitat, as long as sufficient resting/denning structures are retained.** A decision tool that will allow managers to evaluate project areas for their suitability as female fisher home ranges and to adjust prescriptions accordingly is being developed for the Sierra National Forest (see box 7.1-2). **Managers could also benefit if similar fisher home range habitat "templates" were developed for other areas where sufficient data on the vegetation characteristics of home ranges have been collected by researchers.**

Based upon reviews of relevant science, members of the synthesis team concluded that **one of the most scientifically and economically defensible ways to protect biodiversity in the Sierra Nevada—including the habitat of martens and fishers—is to promote prescribed fire and managed wildfire for its beneficial ecological effects,** including the capacity to make the forests of the Sierra Nevada more resilient to climate change. Fire is a disturbance that has historically influenced the vegetation structure and composition in the synthesis area and produced patterns to which the fauna and flora of the area have adapted. Chapters 1.2, "Integrative Approaches: Promoting Socioecological Resilience" and 1.3, "Synopsis of Emergent Approaches," provide more details about this approach. **To minimize impact on individual fishers, prescribed fire and other treatments as needed could be dispersed over space and time.** Testing the hypotheses discussed under Information Gaps (below) in a rigorous assessment framework can lead to better guidelines for the spatial and temporal application of treatments.

**Part of an assessment framework is a credible monitoring program.** The Sierra Nevada Framework (2001, 2004) specified the development of a fisher monitoring program and a study plan was conceived (Zielinski and Mori 2001) that led to annual occupancy monitoring beginning in 2002. Analysis of the first 8 years of sampling data revealed that occupancy was stable over that period (Zielinski et al. 2012). Results of **this population monitoring program could be reconciled with multiscale habitat monitoring for a dual-monitoring approach (population and habitat)** in the future. This combined monitoring program will reassure us that the assumptions we are making about restoring resilient forest ecosystems with the use of prescribed fire and some mechanical treatment of surface and ladder fuels (see chapter 1.2) will indeed produce the amount and distribution of habitat that favors the persistence of fishers and martens.

Finally, of great concern is the recent news that rodenticide, most likely associated with marijuana cultivation, may be a new source of morbidity and mortality in fishers (Gabriel et al. 2012b). **Reducing the application of rodenticides and remediating the environmental damages that have already occurred is an acute need.**

## Climate Change Implications—Marten and Fisher

Lawler et al. (2012) investigated the potential direct and indirect effects of climate change on select species of the genus *Martes.* Climate change predictions suggest that the range of the Pacific marten in California will contract to the north and move up in elevation over the coming century (Lawler et al. 2012). Furthermore, warming climate may favor the upward elevation expansion of fishers into areas currently

occupied by martens (increasing potential competition), and marten habitat will become less common and more fragmented (Lawler et al. 2012). This is because the biggest predicted change in forests in California is the increase in mixed woodland and hardwood-dominated forest types and the reduction in conifer-dominated forest types (Lenihan et al. 2003). Because oaks—especially California black oaks—are a key component of fisher habitat, floristic changes may benefit fishers as long as temperature effects do not result in upward range shifts. Reductions in snowpack, as a result of climate change, could also favor fishers, because deep snow normally excludes fishers from marten habitat in winter (Krohn et al. 1997).

Climate change is also predicted to change fire regimes, increasing fire frequency, area, and intensity (e.g., Flannigan et al. 2000), and these changes are expected to result in loss of late-seral habitat important to both species (McKenzie et al. 2004). Decreases in the density of large conifer and hardwood trees and canopy cover are projected as fire severity increases (Lawler et al. 2012). As these factors are closely related to fisher rest site and home range use in the southern Sierra Nevada (Purcell et al. 2009, Zielinski et al. 2004b), the expectation is for an overall decrease in the availability of fisher habitat. The largest climate impacts to these species will probably occur at the southernmost portion of their ranges (the southern Sierra Nevada) (Lawler et al. 2012). The authors recommend protecting fisher habitat through targeted fuels treatments, and applying more liberal fire management policies to naturally ignited fires during moderate weather conditions.

The change in marten distribution at the SEF (Moriarty et al. 2011) appeared to occur rapidly owing to the influence of traditional timber harvest methods during the mid to late 1900s. It occurred more rapidly than changes in the flora and fauna that affect marten populations might be expected to change because of a warming climate. Yet the marten is a species that may not fare well given the predicted changes in vegetation distribution as a result of a warming climate. The true fir forests where martens typically occur are predicted to diminish in area (Lenihan et al. 2003, Mortenson 2011), resulting in a poor prognosis for martens (Lawler et al. 2012). Climate change may also increase fire frequency and intensity in the upper montane zone, calling for increased levels of thinning treatments in this elevation, which may also diminish marten habitat.

## Information Gaps

Purcell et al. (2012) summarized some of the gaps in knowledge that are preventing application of science to the management of fisher and marten habitat. They noted that there is a great deal of uncertainty around predicting impacts on marten and fisher habitat, particularly cumulative effects. This is largely because our knowledge

of how habitat change influences survival and reproduction is limited, and because we do not yet understand how landscape heterogeneity affects these species at multiple scales. Managing for appropriate stand conditions in terms of density and abundance of large trees may be insufficient if the nature of the arrangement of these stands on the landscape is not also considered. If forests of the future will be more heterogeneous, and this heterogeneity will be a result of a strategic mixture of, for example, three types of patches: (1) high vegetation density, (2) low vegetation density resulting from thinning, and (3) openings—then it will be critical to understand how much of each should occur in landscapes managed for fishers and martens. In particular, resource managers need information about the necessary extent and connectivity of older forest patches, and the spatial heterogeneity and composition of the remaining landscape. Research is moving in this direction (e.g., Thompson et al. 2011), but we cannot yet provide these recommendations. Nor can we determine how fishers will respond to landscapes that have been managed to include active fire regimes, because there are too few of those landscapes available for study or they occur in atypical landscape settings.

Central to moving forward in treating forest fuels is the need to understand the tradeoff between the loss of habitat value that occurs during proactive fuels treatments (when surface fuels are reduced or canopies are thinned), and the loss of habitat that occurs when untreated stands are consumed by wildfire. Some simulation work has been done that indicates that the indirect negative effects of treatments are justified, at least in terms of modeled fisher habitat (Scheller et al. 2011). However, much more work needs to be done on this subject for martens and fishers. Ongoing field studies on martens in the Cascade Range (see box 7.1-2) are seeking to understand the direct effects of fuels treatments on these important wildlife species. Whether animals stay or relocate—and for how long—during management activities is important to know. More critical, however, is how to allocate treatments in space and time so that predicted fire intensity and the distribution of habitat are within acceptable ranges. There are examples of research that lead in this direction (e.g., Cushman and McGarigal 2007, Thompson et al. 2011), but this topic needs more urgent attention and results. Finally, it is important to note that our lack of knowledge about the effects of fuels treatments on fishers and marten extends to their prey. We know very little about the effects of management activities on important prey species and on foraging behavior.

**Central to moving forward in treating forest fuels is the need to understand the tradeoff between the loss of habitat value that occurs during proactive fuels treatments (when surface fuels are reduced and/or canopies are thinned), and the loss of habitat that occurs when untreated stands are consumed by wildfire.**

Future work will need to explore the effect of understory management on fishers and martens. It is understood that treating surface fuels (shrubs and downed wood) and ladder fuels is necessary, and perhaps sufficient, to reduce the potential for high-intensity fires (Agee and Skinner 2005), and that this will have only modest

**Box 7.1-2**
## Pending Research and Monitoring on Marten and Fisher

**Pending studies of effects of fuels treatments—**

- Field studies on martens are being directed by Keith Slauson (Pacific Northwest Research Station [PNW]) and Katie Moriarty (Oregon State University) in the Cascade Range, and field studies on fishers are being directed by Craig Thompson and Kathryn Purcell (Pacific Southwest Research Station [PSW]) in the Cascade Range and the Sierra Nevada. These studies are expected to help understand the direct effects of fuels treatments on these important wildlife species.
- Katie Moriarity is studying the size of openings that martens will cross in the Sierra Nevada and Cascade Range.
- Craig Thompson is directing new research at Kings River (Sierra National Forest) to understand how females with kits respond to nearby management activities (i.e., people, heat and smoke from prescribed fire).

**Other ongoing studies—**

- Keith Slauson and Bill Zielinski (PSW) began a 4-year study in 2008 to evaluate the effects of ski area development and use on home range and demography of marten populations. Field work is completed and a final report is pending.
- Research at both Kings River (led by Craig Thompson) and by the Sierra Nevada Adaptive Management Project (currently led by Rick Sweitzer and formerly by Reginald Barrett, University of California–Berkeley) is investigating various causes of fisher mortality, including predators, road kill, and rodenticides.
- Mourad W. Gabriel, University of California–Davis, is conducting research on effects on fisher of rodenticides. A subcommittee of the interagency Southern Sierra Fisher Working Group is exploring ways to mitigate this source of mortality.

**Translocation of fisher—**

- Aaron N. Facka, North Carolina State University, is studying the translocation of fisher as part of his Ph.D. research.

**Genetics—**

- Michael K. Schwartz (Rocky Mountain Research Station) is evaluating the genetic data on fisher.

**Connectivity—**

- Preliminary models are available (Spencer and Rustigian-Romsos 2012).

**Decision support tool—**

- PSW researchers led by Craig Thompson are currently developing a decision tool that will allow managers to evaluate project areas for their suitability as female fisher home ranges and to adjust prescriptions accordingly.

effects on the habitat for some species associated with mature forests (Stephens et al. 2012). Focusing on ladder fuels without reducing overstory canopy cover has been considered a compromise that will achieve fuel reduction goals but still maintain habitat for mature forest-associated species. However, these prescriptions have the potential to result in greater homogeneity because residual overstory cover is generally uniformly high, but vertical complexity is generally very low. Additionally, the high residual overstory cover may inhibit regeneration of shade-intolerant species (e.g., oaks and shrubs), which are important habitat elements for fishers. There may, in fact, be undue attention directed to diameter limits and the need to promote and protect large trees, when understory management may be a potentially greater source of conflict between achieving fire goals and fisher habitat goals. Lofroth et al. (2010) concluded that management that reduced or removed understory vegetation may decrease prey availability, disrupt movements, and make fishers more vulnerable to predation. Furthermore, Naney et al. (2012: 39–40) noted that "a successful conservation strategy must…. recognize the importance of understory vegetation to support abundant prey populations and provide adequate fisher cover, and the contribution of diverse native vegetation to fisher habitat and the maintenance of resilient landscapes." It is necessary to determine what levels of surface fuels treatments are compatible with the retention of fisher and marten foraging habitat, and habitat for their prey. It is possible that the approach advocated in PSW-GTR-220 (North et al. 2009), which would retain understory structural diversity on north- and east-facing slopes, may provide sufficient understory for fishers, martens, and their prey, but this remains an assumption to be tested. The ability to describe fisher habitat features using LiDAR (Zhao et al. 2012) is a technological breakthrough that will help characterize treatment effects on understory structure.

Our current understanding of fisher habitat use is also prejudiced by the fact that all fisher research has been conducted in forests where fires have been suppressed. This shortcoming means that we continue to assume that the places that fishers choose for home ranges and for resting sites are the same types of places that fishers would select if forest ecosystems were more heterogeneous, less dense in places, and if fire were a dominant disturbance. Even when we possess this information, however, ecologists do not know how to influence vegetation dynamics to produce habitat that will replace the habitat lost to different stressors. Dense stands of preferred species, without the action of fire or thinning, will not guarantee the replacement of large conifers and oaks for use as resting sites. Maintaining habitat in riparian areas and on topographic positions that may have burned less frequently, and at times more severely—as advocated by North et al. (2009)—may help provide

resting habitat elements, as well as connectivity, without significantly reducing the effectiveness of treatments designed to restore resilient forests. However, the resulting habitat connectivity in landscapes managed with these objectives is unknown. New analytical tools (e.g., Thompson et al. 2011, Zielinski et al. 2010) will help evaluate the merits of landscapes that develop under these new management regimes, but the tools may be inappropriate if they are modeled on forest conditions indicative of fire-suppressed forests.

We also still lack important information about specific life-history characteristics, such as reproductive site requirements for martens and fishers, including their requirements for den trees (parturition sites) and denning habitat at multiple spatial scales (Purcell et al. 2012). As suggested in PSW-GTR-220 (North et al. 2009), one way to help ensure the retention of key forest structures would be to provide a list of attributes and representative photos of resting and denning structures for use by marking crews (see Lofroth et al. 2010 for descriptions of the specific types of structures used by fishers for resting and denning). It is one thing to identify these potential structures, but another to understand the effects of nearby disturbance, including prescribed fire, on the occupant(s)—especially if they are reproductive females (see box 7.1-2 for ongoing work on how females with kits respond to nearby management activities). However, much more work needs to be done to determine whether the administration of treatments near known dens, and in areas where den locations may not be known but will still be affected, will have tolerable effects on fisher behavior, physiology, and reproductive output. And, finally, there is very little known about how fishers use landscapes that have recently burned. Our understanding of the risks fishers face from loss of habitat under these conditions would be advanced with new studies that study the behavior of fishers shortly after a landscape has been transformed by fire.

## References

**Agee, J.K.; Skinner, C.K. 2005.** Basic principles of forest fuel reduction treatments. Forest Ecology and Management. 211(1–2): 83–96.

**Ager, A.A.; Finney, M.A.; Kerns, B.K.; Maffei, H. 2007.** Modeling fire risk to northern spotted owl (*Strix occidentalis caurina*) habitat in central Oregon, USA. Forest Ecology and Management. 246: 45–56.

**Andruskiw, M.; Fryxell, J.; Thompson, I.D.; Baker, J.A. 2008.** Habitat-mediated variation in predation risk by the American marten. Ecology. 89: 2273–2280.

**Aubry, K.B.; Lewis, J.C. 2003.** Extirpation and reintroduction of fishers (*Martes pennanti*) in Oregon: implications for their conservation in the Pacific states. Biological Conservation. 114: 79–90.

**Aubry, K.B.; Raley, C.M.; Buskirk, S.W.; Zielinski, W.J.; Schwartz, M.K.; Golightly, R.T.; Purcell, K.L.; Weir, R.D.; Yaeger, J.S. 2013.** Meta-analysis of habitat selection at resting sites by fishers in the Pacific coastal states and provinces. Journal of Wildlife Management. 77(5): 965–974.

**Aubry, K.B.; Zielinski, W.J.; Raphael, M.G.; Proulx, G.; Buskirk, S.W., eds. 2012.** Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press. 536 p.

**Baker, J.A. 1992.** Habitat use and spatial organization of pine marten on southern Vancouver Island, British Columbia. Burnaby, BC: Simon Fraser University: 119 p. M.S. thesis.

**Beier, P.; Spencer, W.; Baldwin, R.F.; McRae, B.H. 2011.** Toward best practices for developing regional connectivity maps. Conservation Biology. 25: 879–892.

**Belant, J. 2007.** Human-caused mortality and population trends in American marten and fisher in a U.S. National Park. Natural Areas Journal. 27: 155–160.

**Bissonette, J.A.; Harrison, D.J.; Hargis, C.D.; Chapin, T.G. 1997.** The influence of spatial scale and scale-sensitive properties on habitat selection by American marten. In: Bissonette, J.A., ed. Wildlife and landscape ecology. New York: Springer-Verlag: 368–385.

**Bissonette, J.A.; Fredrickson, R.J.; Tucker, B.J. 1989.** American marten: a case for landscape-level management. Washington, DC: Transactions of the 54th North American Wildlife and Natural Resources Conference: 89–101.

**Bolsinger, C.L.; Waddell, K.L. 1993.** Area of old-growth forests in California, Oregon, and Washington. Resour. Bull. PNW-RB-197. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 29 p.

**Brown, R.N.; Gabriel, M.W.; Wengert, G.; Matthews, S.; Higley, J.M.; Foley, J.E. 2006.** Fecally transmitted viruses associated with pacific fishers (*Martes pennanti*) in northwestern California. Transaction of the Western Section of the Wildlife Society. 42: 40–46.

**Bull, E.L.; Heater, T.W. 2001.** Survival, causes of mortality, and reproduction in the American marten in northeastern Oregon. Northwestern Naturalist. 82: 1–6.

**Bunnell, K.D.; Flinders, J.T.; Wolfe, M.L. 2006.** Potential impacts of coyotes and snowmobiles on lynx conservation in the Intermountain West. Wildlife Society Bulletin. 34: 828–838.

**Buskirk, S.W.; Powell, R.A. 1994.** Habitat ecology of fishers and American martens in Martens, sables and fishers: biology and conservation. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A., eds. Ithaca, NY: Cornell University Press: 283–296.

**Buskirk, S.W.; Ruggiero, L.F. 1994.** American marten. In: Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W.; Lyon, L.J.; Zielinski, W.J., eds. American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-GTR-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 7–37.

**Buskirk, S.W.; Ruggiero, L.F.; Krebs, C.J. 2000.** Habitat fragmentation and interspecific competition: implications for lynx conservation. In: Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W.; Koehler, G.M.; Krebs, C.J.; McKelvey, K.S.; Squires, J.R., eds. Ecology and conservation of lynx in the United States. Gen. Tech. Rep. RMRS-GTR-30WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 83–100.

**Carey, A.B. 1991.** The biology of arboreal rodents in Douglas-fir forests. In: Huff, M.A.; Holthausen, R.S.; Aubry, K.B., tech. coords. Biology and management of old-growth forests. Gen. Tech. Rep. PNW-GTR-276. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1–46.

**Carroll, C. 2007.** Interacting effects of climate change, landscape conversion and harvest on carnivore populations at the range margin: marten and lynx in the northern Appalachians. Conservation Biology. 21: 1092–1104.

**Chapin, T.G.; Harrison, D.J.; Katnik, D.D. 1998.** Influence of landscape pattern on habitat use by American marten in an industrial forest. Conservation Biology. 12: 96–227.

**Collins, B.M.; Everett, R.G.; Stephens, S.L. 2011.** Impacts of fire exclusion and managed fire on forest structure in an old growth Sierra Nevada mixed-conifer forest. Ecosphere. 2(4): article 51.

**Crooks, K.R.; Soulé, M.E. 1999.** Mesopredator release and avifaunal extinctions in a fragmented system. Nature. 400: 563–566.

**Cushman, S.; McGarigal, K. 2007.** Multivariate landscape trajectory analysis: an example using simulation modeling of American marten habitat change under four timber harvest scenarios. In: Bissonette, J.A.; Storch, I., eds. Temporal dimensions of landscape ecology. New York: Springer: 119–140.

**Cushman, S.A.; Raphael, M.G.; Ruggiero, L.F.; Shirk, A.S.; Wasserman, T.N.; O'Doherty, E.C. 2011.** Limiting factors and landscape connectivity: the American marten in the Rocky Mountains. Landscape Ecology. 26: 1137–1149.

**Davis, F.W.; Seo, C.; Zielinski, W.J. 2007.** Regional variation in home-range-scale habitat models for fisher (*Martes pennanti*) in California. Ecological Applications. 17: 2195–2213.

**Dawson, N.G.; Cook, J.A. 2012.** Behind the genes: diversification of North American martens (*Martes americana* and *M. caurina*). In: Aubry, K.; Zielinski, W.; Raphael, M.; Proulx, G.; Buskirk, S., eds. Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press: 23–38.

**Dixon, J.S. 1925.** A closed season needed for fisher, marten, and wolverine in California. California Fish and Game. 11: 23–25.

**Douglas, C.W.; Strickland, M.A. 1987.** Fisher. In: Novak, M.; Baker, J.A.; Obbard, M.E.; Malloch, B., eds. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources and the Ontario Trappers Association: 511–529.

**Drew, G.S. 1995.** Winter habitat selection by American marten (*Martes americana*) in Newfoundland: Why old growth? Logan, UT: Utah State University. 72 p. Ph.D. dissertation.

**Drew, R.E.; Hallett, J.G.; Aubry, K.B.; Cullings, K.W.; Koepf, S.M.; Zielinski, W.J. 2003.** Conservation genetics of the fisher (*Martes pennanti*) based on mitochondrial DNA sequencing. Molecular Ecology. 12: 51–62.

**Ellis, L.M. 1998.** Habitat-use patterns of the American marten in the southern Cascade mountains of California, 1992–1994. Arcata, CA: Humboldt State University. 186 p. M.S. thesis.

**Facka, A.N.; Powell, R.A. 2010.** Translocation of fishers into the northern Sierra Nevada of California. Annual report. Submitted to U.S. Fish and Wildlife Service, California Department of Fish and Game, and Sierra Pacific Industries. Raleigh, NC: University of North Carolina, Department of Biology. 14 p. https://r1.dfg.ca.gov/Portal/LinkClick.aspx?fileticket=ULHGj73p15Y%3D&tabid=832. (9 September 2014).

**Finke, D.L.; Denno, R.F. 2004.** Predator diversity dampens trophic cascades. Nature. 429: 407–410.

**Finke, D.L.; Snyder, W.E. 2010.** Conserving the benefits of predator biodiversity. Biological Conservation. 143: 2260–2269.

**Flannigan, M.D.; Stocks, B.J.; Wotton, B.M. 2000.** Climate change and forest fires. The Science of the Total Environment. 262: 221–229.

**Franklin, J.F.; Fites-Kaufmann, J.A. 1996.** Assessment of late-successional forests of the Sierra Nevada. In: Sierra Nevada ecosystem project: final report to Congress. Vol. II: Assessments and scientific basis for management options. Report No. 37. Davis, CA: Centers for Water and Wildland Resources, University of California: 627–662. Chapter 21.

**Fuller, A.K.; Harrison, D.J. 2005.** Influence of partial timber harvesting on American martens in north-central Maine. Journal of Wildlife Management. 69: 710–722.

**Gabriel, M.W.; Wengert, G.M.; Brown, R.N. 2012a.** Pathogens and parasites of *Martes* species: management and conservation implications. In: Aubry, K.; Zielinski, W.; Raphael, M.; Proulx, G.; Buskirk, S., eds. Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press: 138–185.

**Gabriel, M.W.; Woods, L.W.; Poppenga, R.; Sweitzer, R.A.; Thompson, C.; Matthews, S.M.; Higley, J.M.; Keller, S.M.; Purcell, K.; Barrett, R.H.; Wengert, G.M.; Sacks, B.M.; Clifford, D.L. 2012b.** Anticoagulant rodenticides on our public and community lands: spatial distribution of exposure and poisoning of a rare forest carnivore. PLoS ONE. 7(7):e40163. doi:10.1371/journal.pone.0040163.

**Golightly, R.T.; Penland, T.F.; Zielinski, W.J.; Higley, J.M. 2006.** Fisher diet in the Klamath/North Coast Bioregion. Unpublished report. Arcata, CA: Humboldt State University. http://www.fws.gov/yreka/Fisher/Literature/Golightly%20et%20al%202006%20Fisher%20Diet.pdf. (18 December 2013).

**Grinnell, J.; Dixon, J.S.; Linsdale, J.M. 1930.** Vertebrate natural history of a section of northern California through the Lassen Peak region. Berkeley, CA: University of California Press. 594 p.

**Grinnell, J.; Dixon, J.S.; Linsdale, J.M. 1937.** Fur-bearing mammals of California. Vol. 1. Berkeley, CA: University of California Press. 375 p.

**Hall, E.R. 1981.** The mammals of North America. 2nd edition. New York: John Wiley & Sons. 1300 p.

**Hargis, C.D.; Bissonette, J.A.; Turner, D.L. 1999.** The influence of forest fragmentation and landscape pattern on American martens. Journal of Applied Ecology. 36: 157–172.

**Hayes, J.P.; Cross, S.P. 1987.** Characteristics of logs used by western red-backed voles, *Clethrionomys californicus*, and deer mice, *Peromyscus maniculatus.* Canadian Field-Naturalist. 101: 543–546.

**Heinemeyer, K.S. 2002.** Translating individual movements into population patterns: American martens in fragmented forested landscapes. Santa Cruz, CA: University of California–Santa Cruz. 300 p. Ph.D. dissertation.

**Jordan, M.J. 2007.** Fisher ecology in the Sierra National Forest, California. Berkeley, CA: University of California–Berkeley. 244 p. Ph.D. dissertation.

**Kirk, T.A.; Zielinski, W.J. 2009.** Developing and testing a landscape habitat suitability model for the American marten (*Martes americana*) in the Cascades mountains of California. Landscape Ecology. 24: 759–773.

**Kirk, T.A.; Zielinski, W.J. 2010.** Modeling functional habitat connectivity of the American marten (*Martes americana*) in northeastern California using least-cost corridor modeling. Unpublished report. Arcata, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 43 p. http://www.sierraforestlegacy.org/Resources/Conservation/SierraNevadaWildlife/AmericanMarten/AM-Kirk%20and%20Zielinski2010.pdf. (18 December 2013).

**Knaus, B.J.; Cronn, R.; Liston, A.; Pilgrim, K.; Schwartz, M.K. 2011.** Mitochondrial genome sequences illuminate maternal lineages of conservation concern in rare carnivore. BMC Ecology. 11: 10.

**Koen, E.L.; Bowman, J.; Garroway, C.J.; Mills, S.C.; Wilson, P.J. 2012.** Landscape resistance and American marten gene flow. Landscape Ecology. 27: 29–43.

**Krohn, W.B.; Hoving, C.; Harrison, D.; Phillips, D.; Frost, H. 2004.** *Martes* foot-loading and snowfall patterns in eastern North America: implications to broad-scale distributions and interactions of mesocarnivores. In: Harrison, D.; Fuller, A.; Proulx, G., eds. Martens and fishers (*Martes*) in human altered landscapes: an international perspective. New York: Springer Science+Business Media: 115–131.

**Krohn, W.B.; Kenneth, D.E.; Randall, B.B. 1995.** Relations among fishers, snow, and martens: development and evaluation of two hypotheses. Forestry Chronicle. 71: 97–105.

**Krohn, W.B.; Zielinski, W.J.; Boone, R.B. 1997.** Relations among fishers, snow, and martens in California: results from small-scale spatial comparisons. In: Proulx, G.; Bryant, H.; Woodard, P., eds. *Martes*: taxonomy, ecology, techniques, and management. Edmonton, AB: Provincial Museum of Alberta: 211–232.

**Kucera, T. 2004.** Ecology of American martens on the Mammoth Mountain Ski area, Inyo National Forest, California. Bishop, CA: U.S. Department of Agriculture, Forest Service, Inyo National Forest. [Pages unknown].

**Kucera, T.E.; Zielinski, W.J.; Barrett, R. 1995.** Current distribution of the American marten, *Martes americana*, in California. California Fish and Game. 81: 96–103.

**Lacey, R.C.; Clark, T.W. 1993.** Simulation modeling of American marten (*Martes americana*) populations: vulnerability to extinction. Western North American Naturalist. 53: 282–292.

**Laliberte, A.S.; Ripple, W.J. 2004.** Range contractions of North American carnivores and ungulates. Bioscience. 54: 123–138.

**Lawler, J.J.; Safford, H.D.; Girvetz, E.H. 2012.** Martens and fishers in a changing climate. In: Aubry, K.B.; Zielinski, W.J.; Raphael, M.G.; Proulx, G.; Buskirk, S.W., eds. Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press: 371–397.

**Lehmkuhl, J.F.; Kennedy, M.; Ford, E.D.; Singleton, P.H.; Gaines, W.L.; Lind, R.L. 2007.** Seeing the forest for the fuel: integrating ecological values and fuels management. Forest Ecology and Management. 246: 73–80.

**Lenihan, J.M.; Drapek, R.; Bachelet, D.; Neilson, R.P. 2003.** Climate change effects on vegetation distribution, carbon, and fire in California. Ecological Applications. 13: 1667–1681.

**Lindström, E.R.; Brainerd, S.M.; Helldin, J.O.; Overskaug, K. 1995.** Pine marten–red fox interactions: A case of intraguild predation? Annales Zoologici Fennici. 32: 123–130.

**Lofroth, E.C.; Raley, C.M.; Higley, J.M.; Truex, R.L.; Yaeger, J.S.; Lewis, J.C.; Happe, P.J.; Finley, L.L.; Naney, R.H.; Hale, L.J.; Krause, A.L.; Livingston, S.A.; Myers, A.M.; Brown, R.N. 2010.** Conservation of fishers (*Martes pennanti*) in south-central British Columbia, western Washington, western Oregon, and California—volume I: conservation assessment. Denver, CO: U.S. Department of the Interior, Bureau of Land Management. 154 p.

**Long, R.A.; MacKay, P.; Zielinski, W.J.; Ray, J.C., eds. 2008.** Noninvasive survey methods for carnivores. Washington, DC: Island Press. 400 p.

**Martin, S. 1987.** Ecology of the pine marten (*Martes americana*) at Sagehen Creek, California. Berkeley, CA: University of California–Berkeley. 446 p. Ph.D. dissertation.

**Martin, S.K. 1994.** Feeding ecology of American martens and fishers. In: Buskirk, S.; Harestad, A.; Raphael, M.; Powell, R., eds. Martens, sables, and fishers. Ithaca, NY: Comstock Publishing Associates, Cornell University Press: 297–315.

**Martin, S.K.; Barrett, R.H. 1991.** Resting site selection by marten at Sagehen Creek, California. Northwestern Naturalist. 72: 37–42.

**McDonald, P. 1990.** California black oak. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: Vol. 2. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 661–671.

**McKelvey, K.S.; Johnston, J.D. 1992.** Historical perspectives on forests of the Sierra Nevada and the Transverse Ranges of southern California: forest conditions at the turn of the century. In: Verner, J.; McKelvey, K.S.; Noon, B.R.; Gutierrez, R.J.; Gould, G.I.; Beck, T.W., eds. The California spotted owl: a technical assessment of its current condition. Gen. Tech. Rep. PSW-GTR-133. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 225–246.

**McKenzie, D.; Gedalof, Z.; Peterson, D.L.; Mote, P. 2004.** Climatic change, wildfire, and conservation. Conservation Biology. 18: 890–902.

**Moriarty, K.M.; Zielinski, W.J.; Gonzales, A.G.; Dawson, T.E.: Boatner, K.M.; Wilson, C.A.; Schlexer, F.V.; Pilgrim, K.L.; Copeland, J.P.; Schwartz M.K. 2009.** Wolverine confirmation in California after nearly a century: Native or long-distance immigrant? Northwest Science. 83: 154–162.

**Moriarty, K.M.; Zielinski, W.J.; Forsman, E.D. 2011.** Decline in American marten occupancy rates at Sagehen Experimental Forest, California. Journal of Wildlife Management. 75: 1774–1787.

**Mortenson, L.A. 2011.** Spatial and ecological analysis of red fir decline in California using FIA data. Corvallis, OR: Oregon State University. 96 p. M.S. thesis.

**Naney, R.H.; Finley, L.L.; Lofroth, E.C.; Happe, P.J.; Krause, A.L.; Raley, C.M.; Truex, R.L.; Hale, L.J.; Higley, J.M.; Kosic, A.D.; Lewis, J.C.; Livingston, S.A.; Macfarlane, D.C.; Myers, A.M.; Yaeger, J.S. 2012.** Conservation of fishers (*Martes pennanti*) in south-central British Columbia, western Washington, western Oregon, and California—volume III: threat assessment. Denver, CO: U.S. Department of the Interior, Bureau of Land Management. 55 p.

**North, M.; Stine, P.; O'Hara, K.; Zielinski, W.; Stephens, S. 2009.** An ecosystem management strategy for Sierran mixed-conifer forests. Gen. Tech. Rep. PSW-GTR-220. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 49 p.

**Perrine, J.D.; Campbell, L.A.; Green, G.A. 2010.** Sierra Nevada red fox (*Vulpes vulpes necator*): a conservation assessment. Tech. Rep. R5-FR-010. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 42 p.

**Porter, A.D.; St Clair, C.C.; de Vries, A. 2005.** Fine-scale selection by marten during winter in a young deciduous forest. Canadian Journal of Forest Research. 35: 901–909.

**Potvin, F.; Belanger, L.; Lowell, K. 2000.** Marten habitat selection in a clearcut boreal landscape. Conservation Biology. 14: 844–857.

**Powell, R.A. 1993.** The fisher: life history, ecology and behavior. 2nd ed. Minneapolis, MN: University of Minnesota Press. 237 p.

**Powell, R.A.; Buskirk, S.W.; Zielinski, W.J. 2003.** Fisher and marten (*Martes pennanti* and *Martes americana*). In: Feldhamer, G.; Thompson, B.; Chapman, J., eds. Wild mammals of North America. Baltimore, MD: Johns Hopkins University Press: 635–649.

**Powell, R.A.; Zielinski, W.J. 1994.** Fisher. In: Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W.; Zielinski, W.J., eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experimental Station: 38–73.

**Purcell, K.L.; Mazzoni, A.K.; Mori, S.R.; Boroski, B.B. 2009.** Resting structures and resting habitat of fishers in the southern Sierra Nevada, California. Forest Ecology and Management. 258: 2696–2706.

**Purcell, K.L.; Thomas, C.M.; Zielinski, W.J. 2012.** Fishers and American martens. In: North, M., ed. Managing Sierra Nevada forests. Gen. Tech. Rep. PSW-GTR-237. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 47–60.

**Raley, C.M.; Lofroth, E.C.; Truex, R.L.; Yaeger, J.S.; Higley, J.M. 2012.** Habitat ecology of fishers in western North America: a new synthesis. In: Aubry, K.B.; Zielinski, W.J.; Raphael, M.J.; Proulx, G.; Buskirk, S.W., eds. Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press: 231–254.

**Ripple, W.J.; Beschta, R.L. 2004.** Wolves and the ecology of fear: Can predation risk structure ecosystems? Bioscience. 54: 755–766.

**Roberts, S.L.; van Wagtendonk, J.W.; Miles, A.K.; Kelt, D.A. 2011.** Effects of fire on spotted owl site occupancy in a late-successional forest. Biological Conservation. 144: 610–619.

**Roemer, G.W.; Gompper, M.E.; Van Valkenburgh, B. 2009.** The ecological role of the mammalian mesocarnivore. Bioscience. 59: 165–173.

**Roloff, G.J.; Mealey, S.P.; Bailey, J.D. 2012.** Comparative hazard assessment for protected species in a fire-prone landscape. Forest Ecology and Management. 277: 1–10.

**Roy, D.G.; Vankat, J.L. 1999.** Reversal of human-induced vegetation changes in Sequoia National Park, California. Canadian Journal of Forest Research. 29: 399–412.

**Sato, J.J.; Wolsan, M.; Prevosti, F.J.; D'Elía, G.; Begg, C.; Begg, K.; Hosoda, T.; Campbell, K.L.; Suzuki, H. 2012.** Evolutionary and biogeographic history of weasel-like carnivorans (Musteloidea). Molecular Phylogenetics and Evolution. 63(3): 745–757.

**Scheller, R.M.; Spencer, W.D.; Rustigian-Romsos, H.; Syphard, A.D.; Ward, B.C.; Strittholt, J.R. 2011.** Using stochastic simulation to evaluate competing risks of wildfires and fuels management on an isolated forest carnivore. Landscape Ecology. 26: 1491–1504.

**Scholl, A.E.; Taylor, A.H. 2010.** Fire regimes, forest change, and self-organization in an old-growth mixed-conifer forest, Yosemite National Park, USA. Ecological Applications. 20: 362–380.

**Slauson, K.M.; Zielinski, W.J.; Kirk, T.A. 2010.** Effects of forest restoration on mesocarnivores in the northern redwood region of northwestern California. Arcata, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 29 p. http://www.fws.gov/arcata/es/mammals/HumboldtMarten/documents/Effects%20of%20Forest%20Restoration%20on%20Mesocarnivores_FINAL2.pdf. (18 December 2013).

**Spencer, W.D. 1987.** Seasonal rest-site preferences of pine martens in the northern Sierra Nevada. Journal Wildlife Management. 51: 616–621.

**Spencer, W.D.; Barrett, R.H.; Zielinski, W.J. 1983.** Marten habitat preferences in the northern Sierra Nevada. Journal Wildlife Management. 47: 1181–1186.

**Spencer, W.D.; Beier, P.; Penrod, K.; Winters, K.; Paulman, C.; Rustigian-Romsos, H.; Strittholt, J.; Parisi, M.; Pettler, A. 2010.** California essential habitat connectivity project: a strategy for conserving a connected California. Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration. http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=18366. (18 December 2013).

**Spencer, W.D.; Rustigian-Romsos, H. 2012.** Decision-support maps and recommendations for conserving rare carnivores in the interior mountains of California. Corvallis, OR: Conservation Biology Institute. 49 p.

**Spencer, W.D.; Rustigian-Romsos, H.; Strittholt, J.R.; Scheller, R.; Zielinski, W.J.; Truex, R. 2011.** Using occupancy and population models to assess habitat conservation opportunities for an isolated carnivore population. Biological Conservation. 144: 788–803.

**Stephens, S.L.; McIver, J.D.; Boerner, R.E.J.; Fettig, C.J.; Fontaine, J.B.; Hartsough, B.R.; Kennedy, P.; Schwilk, D.W. 2012.** Effects of forest fuel reduction treatments in the United States. BioScience. 62: 549–560.

**Thompson, C.M.; Purcell, K.L.; Garner, J.; Green, R. 2010.** Kings River fisher project: progress report 2007–2010. Fresno, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 37 p.

**Thompson, C.M.; Zielinski, W.J.; Purcell, K.L. 2011.** The use of landscape trajectory analysis to evaluate management risks: a case study with the fisher in the Sierra National Forest. Journal of Wildlife Management. 75: 1164–1176.

**Thompson, I.D. 1994.** Marten populations in uncut and logged boreal forests in Ontario. Journal of Wildlife Management. 58: 272–280.

**Thompson, I.D.; Fryxell, J.; Harrison, D.J. 2012.** Improved insights into use of habitat by American martens. In: Aubry, K.; Zielinski, W.; Raphael, M.; Proulx, G.; Buskirk, S., eds. Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press: 209–230.

**Truex, R.L.; Zielinski, B. 2013.** Short-term effects of fire and fire surrogate treatments on fisher habitat in the Sierra Nevada. Forest Ecology and Management. 293: 85–91.

**Tucker, J.M.; Schwartz, M.K.; Truex, R.L.; Pilgrim, K.L.; Allendorf, F.W. 2012.** Historical and contemporary DNA indicate fisher decline and isolation occurred prior to European settlement of California. PLos One. 7(12): e52803. doi:10.1371/journal.pone.0052803.

**Underwood, E.C.; Viers, J.H.; Quinn, J.F.; North, M. 2010.** Using topography to meet wildlife and fuels treatment objectives in fire-suppressed landscapes. Environmental Management. 46: 809–819.

**U.S. Department of Agriculture, Forest Service [USDA FS]. 2001.** Sierra Nevada forest plan amendment: final environmental impact statement. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 55 p. http://www.sierraforestlegacy.org/Resources/Conservation/LawsPoliciesRegulation/KeyForestServicePolicy/SierraNevadaFramework/Framework-FSROD01.pdf. (18 December 2013).

**U.S. Department of Agriculture, Forest Service [USDA FS]. 2004.** Sierra Nevada forest plan amendment: final supplemental environmental impact statement. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsBdev3_046095.pdf. (18 December 2013).

**Van de Water, K.M.; Safford, H.D. 2011.** A summary of fire frequency estimates for California vegetation before Euro-American settlement. Fire Ecology. 7: 26–58.

**Waters, J.R.; Zabel, C.J. 1995.** Northern flying squirrel densities in fir forests of northeastern California. Journal of Wildlife Management. 59: 858–866.

**Weir, R.D.; Phinney, M.; Lofroth, E.C. 2012.** Big, sick, and rotting: why tree size, damage, and decay are important to fisher reproductive habitat. Forest Ecology and Management. 265: 230–240.

**Weir, R.D.; Corbould, F.B. 2010.** Factors affecting landscape occupancy by fishers in north-central British Columbia. Journal of Wildlife Management. 74: 405–410.

**Wisely, S.M.; Buskirk, S.W.; Russell, G.A.; Aubry, K.B.; Zielinski, W.J.; Lessa, E.P. 2004.** Genetic diversity and structure of the fisher (*Martes pennanti*) in a peninsular and peripheral metapopulation. Journal of Mammalogy. 85: 640–648.

**Zhao, F.; Sweitzer, R.A.; Guo, Q.; Kelly, M. 2012.** Characterizing habitats associated with fisher den structures in the Southern Sierra Nevada, California using discrete return lidar. Forest Ecology and Management. 280: 112–119.

**Zielinski, W.J.; Baldwin, J.A.; Truex, R.L.; Tucker, J.M.; Flebbe, P.A. 2012.** Estimating trend in occupancy for the southern Sierra fisher (*Martes pennanti*) population. Journal of Fish and Wildlife Management. http://fwspubs.org/doi/pdf/10.3996/012012-JFWM-002. (18 December 2013).

**Zielinski, W.J.; Duncan, N.P.; Farmer, E.C.; Truex, R.L.; Clevenger, A.P.; Barrett, R.H. 1999.** Diet of fishers (*Martes pennanti*) at the southernmost extent of their range. Journal of Mammalogy. 80: 961–971.

**Zielinski, W.J.; Gray, A.N.; Dunk, J.R.; Sherlock, J.W.; Dixon, G.E. 2010.** Using Forest Inventory and Analysis data and the Forest Vegetation Simulator to predict and monitor fisher (*Martes pennanti*) resting habitat suitability. Gen. Tech. Rep. PSW-GTR-232. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 31 p.

**Zielinski, W.J.; Kucera, T.E.; Barrett, R.H. 1995.** Current distribution of the fisher, *Martes pennanti*, in California. California Fish and Game. 81: 104–112.

**Zielinski, W.J.; Mori, S. 2001.** What is the status and change in the geographic distribution and relative abundance of fishers? Adaptive management strategy, Sierra Nevada framework, study plan. Arcata, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

**Zielinski, W.J.; Slauson, K.M.; Bowles, A.E. 2008.** Effects of off-highway vehicle use on the American marten. Journal of Wildlife Management. 72: 1558–1571.

**Zielinski, W.J.; Slauson, K.M.; Carroll, C.R.; Kent, C.J.; Kudrna, D.G. 2001.** Status of American martens in coastal forests of the Pacific states. Journal of Mammalogy. 82: 478–490.

**Zielinski, W.J.; Spencer, W.D.; Barrett, R.D. 1983.** Relationship between food habits and activity patterns of pine martens. Journal of Mammalogy. 64: 387–396.

**Zielinski, W.J.; Truex, R.L.; Dunk, J.R.; Gaman, T. 2006.** Using forest inventory data to assess fisher resting habitat suitability in California. Ecological Applications. 16: 1010–1025.

**Zielinski, W.J.; Truex, R.L.; Schlexer, F.V.; Campbell, L.A.; Carroll, C. 2005.** Historical and contemporary distributions of carnivores in forests of the Sierra Nevada, California, U.S.A. Journal of Biogeography. 32: 1385–1407.

**Zielinski, W.J.; Truex, R.L.; Schmidt, G.A.; Schlexer, F.V.; Schmidt, K.N.; Barrett, R.H. 2004a.** Resting habitat selection by fishers in California. Journal of Wildlife Management. 68: 475–492.

**Zielinski, W.J.; Truex, R.L.; Schmidt, G.A.; Schlexer, F.V.; Schmidt, K.N.; Barrett, R.H.; O'Shea, T.J. 2004b.** Home range characteristics of fishers in California. Journal of Mammalogy. 85: 649–657.