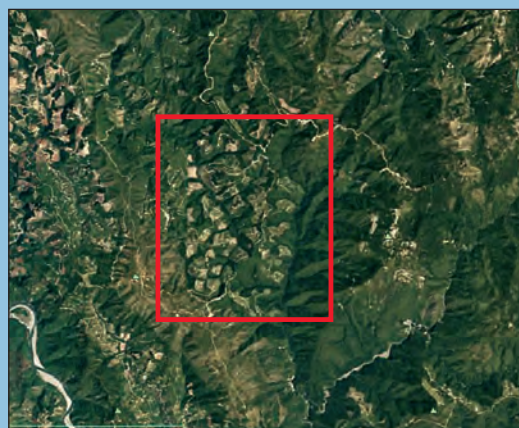
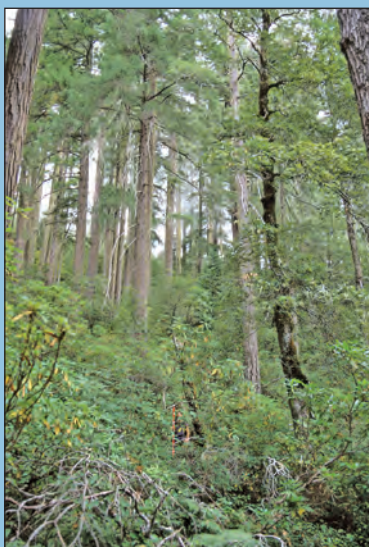


A Conservation Assessment and Strategy for the Humboldt Marten in California and Oregon

Keith M. Slauson, Gregory A. Schmidt, William J. Zielinski, Phillip J. Detrich, Richard L. Callas, James Thraillkill, Brenda Devlin-Craig, Desiree A. Early, Keith A. Hamm, Kristin N. Schmidt, Amber Transou, and Christopher J. West



This publication is available online at www.fs.fed.us/psw/.

Pacific Southwest Research Station
800 Buchanan Street
Albany, CA 94710

Disclaimer

The findings and conclusions in this publication are those of the authors and do not necessarily represent the view or position of their respective agencies. The use of trade or firm names in this publication is for reader information and does not imply endorsement by the respective agencies of any product or service.

Authors

Keith M. Slauson is a research fellow and **William J. Zielinski** is a research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Lab, 1700 Bayview Drive, Arcata, CA 95521, keithmslauson@fs.fed.us, bzielinski@fs.fed.us; **Gregory A. Schmidt** is a fish and wildlife biologist, U.S. Department of the Interior, Fish and Wildlife Service, Arcata Field Office, 1655 Heindon Road, Arcata, CA 95521, gregory_schmidt@fws.gov; **Phillip J. Detrich** is an environmental consultant, PJD Environmental Consulting, 411 McCloud Avenue, Mount Shasta, CA 96067, fishbirdco@gmail.com; **Richard L. Callas** is a senior environmental scientist, California Department of Fish and Wildlife, North Region, 601 Locust Street, Redding, CA 96001, Richard.Callas@wildlife.ca.gov; **James Thrailkill** is a field supervisor, U.S. Department of the Interior, Fish and Wildlife Service, Roseburg Field Office, 2900 NW Stewart Parkway, Roseburg, OR 97471, jim_thrailkill@fws.gov; **Brenda Devlin-Craig** is a wildlife biologist, U.S. Department of Agriculture, Forest Service, Smith River National Recreation Area, 10600 Highway 199/P.O. Box 228, Gasquet, CA 95543, bdevlin@fs.fed.us; **Desiree A. Early** is a terrestrial biologist and **Keith A. Hamm** is a conservation planning manager, Green Diamond Resource Company, 900 Riverside Drive, Korb, CA 95550, DEarly@greendiamond.com, khamm@greendiamond.com; **Kristin N. Schmidt** is a wildlife biologist, Redwood National and State Parks, P.O. Box 7/121200 Highway 101, Orick, CA 95555, kristin_schmidt@nps.gov; **Amber Transou** is a senior environmental scientist, California State Parks, North Coast Redwoods District, P.O. Box 2006, Eureka, CA 95502, Amber.Transou@parks.ca.gov; and **Christopher J. West** is a senior wildlife biologist, Yurok Tribe, Wildlife Program, 190 Klamath Boulevard, Klamath, CA 95548, cwest@yuroktribe.nsn.us.

Abstract

Slauson, Keith M.; Schmidt, Gregory A.; Zielinski, William J.; Detrich, Phillip J.; Callas, Richard L.; Thraillkill, James; Devlin-Craig, Brenda; Early, Desiree A.; Hamm, Keith A.; Schmidt, Kristin N.; Transou, Amber; West, Christopher J. 2019. A conservation assessment and strategy for the Humboldt marten in California and Oregon. Gen. Tech. Rep. PSW-GTR-260. Arcata, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 124 p.

This report is based on the final version of the Humboldt marten (*Martes caurina humboldtensis*) conservation assessment and strategy submitted on September 30, 2017 by the Humboldt Marten Conservation Group. This assessment and strategy was developed in response to the decline of the Humboldt marten throughout most of its historical range in California and Oregon. The first four chapters synthesize the state of the knowledge on the Humboldt marten and relevant ecological and management aspects of the forest habitats it occupies. The final chapter identifies overall conservation goals, evaluates current threats or impediments to achieving those goals, and identifies a series of conservation actions and information needs that could help to achieve the overall conservation goals.

Keywords: *Martes caurina humboldtensis*, Humboldt marten, coastal California, coastal Oregon, conservation strategy.

Summary

The Humboldt marten (*Martes caurina humboldtensis*) is a medium-size carnivore that historically occurred throughout the coastal forests of northwestern California and Oregon. Decades of unregulated trapping followed by extensive habitat loss and fragmentation from unregulated timber harvesting are likely the two most important historical factors that caused declines in the distribution and abundance of Humboldt martens. This subspecies has been extirpated from greater than 95 percent of its historical range in California, where it is known only from one population numbering fewer than 100 individuals and another smaller population recently detected near the California-Oregon border. Recent genetic analysis has found that coastal Oregon martens, previously recognized as *Martes caurina caurina*, are most genetically similar to the Humboldt subspecies and should be reclassified as *M. c. humboldtensis*. Two known Oregon populations remain, one in the central coast area and one in the south coast. Additional survey effort is needed to fully understand the current distribution in coastal Oregon, but the degree of range contraction is apparently of similar magnitude to that in California.

In recognition of the need to improve the status of the Humboldt marten, the Humboldt Marten Conservation Group (HMCG) was formed in California in 2011. In 2013, as new genetic information suggested that the Humboldt subspecies included coastal Oregon, the HMCG was expanded to include that area. The HMCG is composed of federal, state, tribal, private, and nongovernmental organizations with an interest in conservation and management of the Humboldt marten on public, tribal, and private forests in coastal northwestern California and coastal Oregon. The HMCG recognized the need for an integrated regional approach to address the immediate research and conservation needs for the Humboldt marten, and agreed that developing a conservation assessment and strategy should be the first step toward implementing such an approach.

This conservation assessment is a synthesis of published and unpublished scientific literature on Humboldt marten ecology and habitat relationships. Where appropriate, it also includes relevant published studies on martens from elsewhere in North America. We have included published and unpublished literature through 2016, and anticipate that future updates will incorporate new information. This conservation assessment considers three major topics: (1) biophysical environment, (2) human modifications to the environment, and (3) biological information on martens.

Contemporary detections of Humboldt martens have occurred in three habitat types: (1) moist Douglas-fir (*Pseudotsuga menziesii* (Mirb. Franco) associated forest

types, (2) moist forest types on serpentine soils, and (3) shore-pine (*Pinus contorta* Douglas ex Loudon)-associated dune forests on coastal terraces. A dense, spatially extensive shrub layer typically dominated by shade-tolerant ericaceous species is a consistent feature within these three forest habitat types. The majority of marten detections have occurred in largely unmanaged moist Douglas-fir-associated forest types, where martens select large patches (>80 ha) of late-successional forest as habitat. Research in more intensively managed forest has found some Humboldt martens occupying and reproducing in home ranges composed of a mosaic of younger stands, most of which were harvested more than 20 years ago. Many of these stands contain residual conifers left uncut in earlier harvests, conspicuous numbers of large live and dead conifer trees, and large residual hardwood structures. In this intensively managed landscape, nearly half of the martens monitored have been killed by bobcats (*Lynx rufus*), which select for the young regenerating forests that support their two most important prey species, dusky-footed woodrats (*Neotoma fuscipes*) and brush rabbits (*Sylvilagus bachmani*). This pattern of high predation rates by habitat generalist carnivores in intensively managed landscapes is consistent with studies of North American martens elsewhere. Because survival is the most sensitive vital rate for martens, predation related to landscape composition likely represents a limiting factor for Humboldt marten populations. Collectively, these results suggest that the management and restoration of suitable habitat for the Humboldt marten will require consideration of multiple spatial scales, including stand, home range, and landscape, to account for marten habitat needs and to mediate interactions that affect their survival.

The diet of the Humboldt marten is composed largely of small mammals, and to a lesser degree birds, with berries and ground-nesting wasps and hornets consumed when they are seasonally available. Sciurids are the most important prey, representing 42 percent of the overall proportion of metabolizable energy, ranging from 29 percent (spring) to 51 percent (summer). Chipmunks (*Tamias* sp.) are the most important sciurid in the summer and fall; when they are less available in winter and spring owing to reduced activity, Humboldt martens increase their use of alternative prey of similar or larger body size, including Humboldt flying squirrels (*Glaucomys oregonensis*) and medium and large birds. The importance of sciurids in Humboldt marten diets is consistent with diets reported by other marten studies from the Pacific States. Collectively, these key prey species use food resources and den and cache sites in large standing woody structures (live and dead) associated with mature and late-successional forest conditions. Between foraging bouts, martens use rest sites to conserve energy and avoid predators, typically selecting the largest

available live and dead woody structures. Humboldt martens typically rest in cavities and platforms in large-diameter live and dead conifers and hardwoods. Additionally, Humboldt martens rest in cavities and chambers associated with downed logs and natural log piles, and less often in slash piles, rock piles, and dense shrub clumps. Female martens are obligate cavity users for reproduction, bearing young in cavities in large-diameter hardwoods and conifers, and often moving young to platforms in trees and snags or cavities near the ground later in the denning season. Marten habitat management at the stand scale will involve maintaining, enhancing, and recruiting suitable resting and denning structures, as well as providing for the needs of important prey.

The overall goal of this conservation strategy is to establish self-sustaining, interacting populations of Humboldt martens within suitable habitat throughout their historical range. To achieve this goal, this conservation strategy uses a three-pronged approach: (1) **protect** existing populations and currently suitable habitat, (2) **reestablish** populations where currently suitable habitat is inaccessible owing to existing dispersal barriers, and (3) **restore** suitable habitat conditions in specific areas to increase population size and distribution. Our first step in developing this strategy was to identify conservation emphasis areas, including (1) extant population areas encompassing the distribution of extant populations; (2) population reestablishment areas, including unoccupied habitat capable of supporting ≥ 5 female marten home ranges; and (3) landscape connectivity areas in currently low-suitability habitat between extant population areas or population reestablishment areas. We mapped these conservation emphasis areas using contemporary survey results and a recently developed rangewide landscape habitat suitability model.

We conducted a threats assessment for the California portion of the assessment area to describe and rank potential threats to martens or their habitat, and identified specific conservation actions and information needs. In California, threat categories with the highest impact levels included large-scale habitat fragmentation, wildfire, and lethal disease. We also identified seven additional medium-level threats and 18 low-level threats. We determined that three high-priority conservation actions—strategic habitat restoration and management, population reestablishment through assisted dispersal, and monitoring of population response to management and stochastic events—could ameliorate most high- and medium-level threats. The strategy also identifies high-priority short-term information needs, including:

- Development of a habitat management guide capable of identifying habitat characteristics most important for supporting marten occupancy, reproduction, and survival at the stand and home range scales.

- Continuing surveys to identify new occupied areas and to monitor the distribution and abundance of known populations.
- Evaluating the potential for maintaining and improving each population reestablishment area.
- Assessing the feasibility of an assisted dispersal program for population reestablishment.
- Determining the habitat associations for key marten predators, and identifying management actions that can reduce predator abundance where martens occur.
- Identifying habitat conditions for successful marten dispersal and developing management recommendations that can maintain or improve these conditions where needed.

In Oregon, contemporary survey efforts are not yet sufficient to guide the identification of conservation emphasis areas or threats assessment processes. The short-term high-priority information needs for Oregon can be met by:

- Conducting surveys to determine the size and distribution of known marten populations using a sampling design capable of tracking long-term changes in size or distribution.
- Evaluating the landscape habitat suitability model for coastal Oregon and refining it with new survey data as necessary.
- Determining the multiscale habitat needs for marten home range occupancy, reproduction, and survival using standardized vegetation sampling methods.
- Determining the population-level impacts of factors contributing to marten mortality, including distribution and frequency of predation, vehicle strikes, legal trapping, and rodenticide poisoning.

Finally, we will seek to maximize the value of new information and management actions by using standardized surveys, population monitoring protocols, and vegetation mensuration techniques throughout the range of the Humboldt marten.

Contents

1	Chapter 1: Introduction
1	Background
5	Geographic Scope
6	Goal and Objectives of the Assessment and Strategy
7	Chapter 2: Biophysical Environment
7	Physical Environment
8	Plant Communities and Natural Disturbance
10	Natural Disturbance
13	Implications for Conservation
15	Chapter 3: Human Modifications to the Environment
15	American Indian Use of Martens
15	American Indian Use of Fire
16	Historical and Contemporary Use and Management of Natural Resources
16	Alteration of Natural Fire Regimes
18	Habitat Loss and Conversion From Timber Harvest
19	Current Conditions and Land Use of Assessment Area
21	Predator Control
21	Climate Change in the Assessment Area
22	Implications for Conservation
25	Chapter 4: Biological Information
25	Description and Taxonomy
29	Historical Distribution: Coastal California and Coastal Oregon
29	Contemporary Distribution and Abundance: Coastal California and Oregon
33	Life History
33	Territoriality
33	Activity Patterns
33	Food Habits and Habitat-Prey Relationships
37	Reproduction
37	Survivorship and Longevity
40	Parasites and Disease
41	Dispersal and Recruitment
42	Population Biology and Dynamics

45	Intraguild Predation and Interspecific Competition
47	Multiscale Habitat Use
48	Microscale Habitat Use: Resting and Denning Structures
51	Stand-Scale Habitat Use
53	Home Range-Scale Habitat Use
56	Landscape-Scale Effects on Habitat Use: Movement, Occupancy, and Population Dynamics
59	Contemporary Landscape Habitat Suitability
63	Implications for Conservation
65	Research and Management Needs in the Assessment Area
67	Chapter 5: Development of the Conservation Strategy Foundation
67	Strategy Goal, Guiding Principles, and Approach
69	State of the Science for Supporting the Development of a Conservation Strategy
69	Overall Strategy Approach
70	Conservation Emphasis Areas
72	Extant Population Areas
77	Population Reestablishment Areas
80	Landscape Connectivity Areas
82	Potential Threats to the Humboldt Marten
83	Classification of Potential Threats
87	Degree of Potential Threat Impacts
88	Conservation Actions
88	Integration of Conservation Actions and Conservation Emphasis Areas
88	High Priority Conservation Actions
94	Next Steps and Key Information Needs for Further Development of the Conservation Strategy
97	Acknowledgments
97	English Equivalents
98	References
117	Appendix 1—Humboldt Marten Conservation Group
119	Appendix 2—Rational for Threats Rankings in California

Chapter 1: Introduction

Background

Until recently, the American marten (*Martes americana*) was the only marten species recognized in North America, occurring in boreal forests, montane coniferous forests, and Atlantic and Pacific coastal forests (Gibilisco 1994). However, the Pacific marten (*Martes caurina*) was recently split from the American marten based on genetic and morphological differences (Dawson and Cook 2012). The range of the Pacific marten occurs largely in montane and coastal coniferous forests west of the Rocky Mountain crest, while the range of the American marten occurs to the north and east of the Rocky Mountain crest. The deep genetic split between these two species of martens in North America is thought to have originated from the persistence of marten populations in two disjunct glacial refugia during the most recent glacial period (Dawson and Cook 2012).

The Humboldt marten (*M. c. humboldtensis*), one of the recognized subspecies of the Pacific marten (Grinnell and Dixon 1926), was historically distributed throughout the coastal, fog-influenced forests of the coast redwood (*Sequoia sempervirens* (Lamb. ex D. Don) Endl.) region in California from northwestern Sonoma County northward to the Oregon border (Grinnell et al. 1937) (fig. 1). Ongoing genetic analyses support the conclusion that there is no genetic distinction between martens in the range of the Humboldt marten subspecies in California and the *M. c. caurina* subspecies in the Oregon Coast Range and that these populations represent a single evolutionary unit (Schwartz et al. 2016, Slauson et al. 2009b). Furthermore, based on the combination of nuclear and mitochondrial DNA analyses, coastal California and coastal Oregon martens are different from interior California and interior Oregon martens representing *M. c. sierrae* in the Marble and Trinity Mountains of northern California, *M. c. caurina* in the Cascade Mountains of Oregon, and *M. c. caurina* in the Olympic and Cascade Mountains of Washington. Based on these collective findings, the range of the Humboldt subspecies has been expanded to include the Oregon Coast Range, historically recognized as that of *M. c. caurina* (Schwartz et al. 2016). For these reasons, this assessment and strategy will focus on the collective distribution of the Humboldt subspecies from its historical range in coastal northwestern California and coastal Oregon.

Throughout this assessment and strategy, we have primarily used published studies within the range of the Pacific marten. Where information from the range of that species is limited or absent, we include relevant references from studies within the range of the American marten. However, confusion may arise when describing older studies conducted in the portion of the historically described range

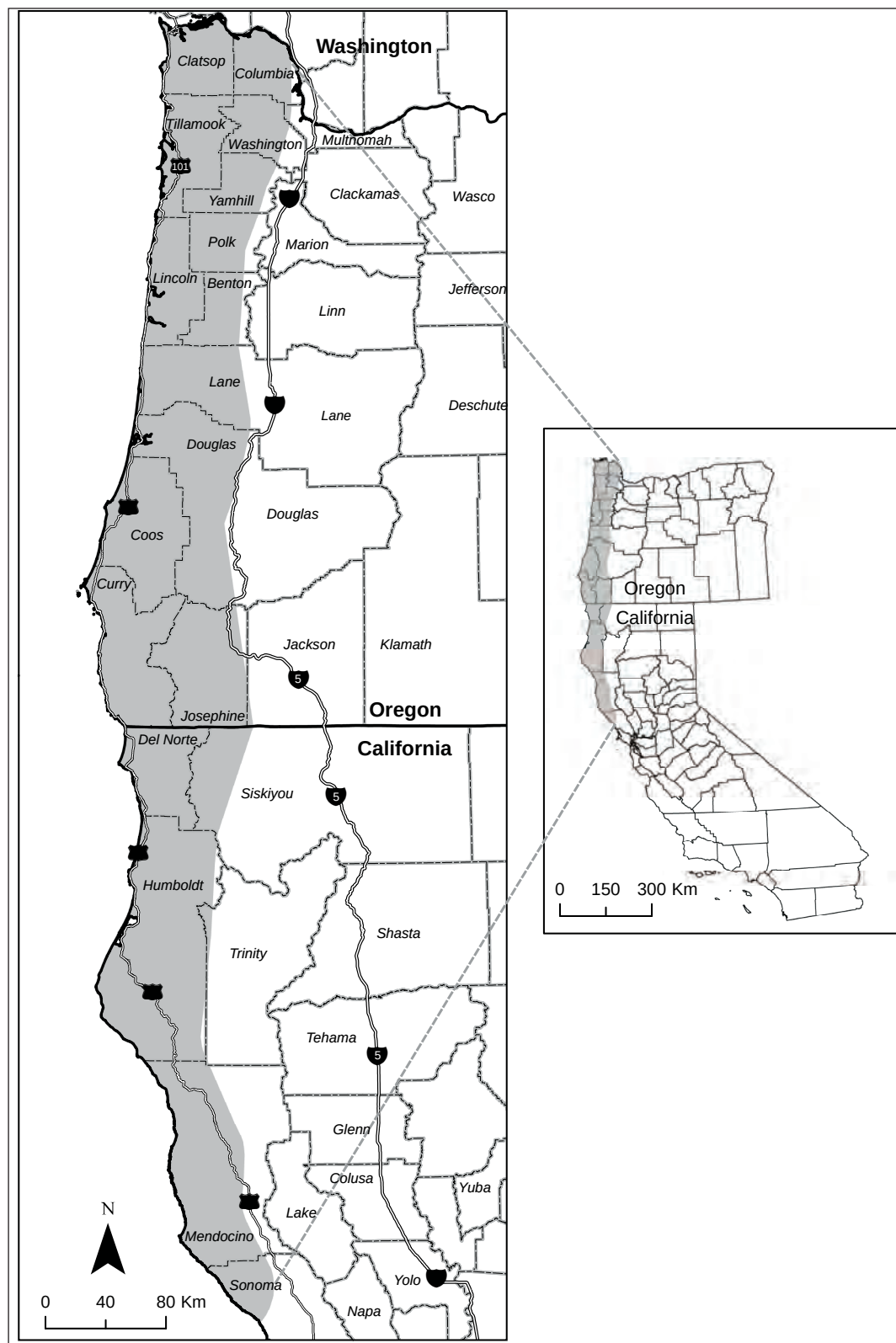


Figure 1—Historical range (shaded gray area) of the Humboldt marten (*Martes caurina humboldtensis*) in coastal California and coastal Oregon. This geographic extent defines the scope of the assessment area.

of the American marten now recognized as that of the Pacific marten. To reduce this potential confusion, we use the current taxonomic designation of Pacific marten when citing studies on the previously designated American marten but which occur within the currently recognized range of the Pacific marten. Throughout the document, we use the following terms in reference to specific marten taxonomical levels: (1) “Humboldt marten” to refer to *M. c. humboldtensis*, representing the subspecies found in the assessment area; (2) “Pacific marten” to refer to the species of marten occupying North America west of the Rocky Mountain crest, including the Humboldt subspecies; (3) “American marten” to refer to the species occupying North America east of the Rocky Mountain crest; and (4) “North American martens” to refer collectively to both Pacific and American marten subspecies.

In North America, martens have a long history of being trapped for their valuable pelts. Martens were trapped in the coastal forests of California and Oregon as early as the late 1800s, and declining harvests of martens were noted in both states in the early 1900s (Dixon 1925, Grinnell et al. 1937, Zielinski et al. 2001). Owing to these declines, the trapping season was closed indefinitely in California in 1946 (Zielinski et al. 2001). Despite similar declines in marten harvest in Oregon since the 1940s (Zielinski et al. 2001), martens are still legally trapped in that state.

While successful marten trapping was declining in the early and mid-1900s, unregulated harvest of redwood forest was increasing. Regulation of timber harvest began in California in the decades following 1960, but by the mid 1990s more than 95 percent of the redwood-associated forests in the historical range of the Humboldt marten had been logged (Fox 1996). A similar magnitude of logging took place in the coastal forests of Oregon (Bolsinger and Waddell 1993). The Pacific marten is closely associated with late-successional coniferous forests (reviewed in Buskirk and Powell 1994, Slauson et al. 2007, and further described below), and North American martens are highly sensitive to the loss and fragmentation of mature forests (Chapin et al. 1998, Hargis et al. 1999, Potvin et al. 2000). Over 70 percent of contemporary detections of Humboldt martens have occurred in large patches (>80 ha) of old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) forest with dense shrub cover, consistent with the habitat selection patterns reported by Slauson et al. (2007). In both coastal California and Oregon, martens have also been detected in moist coniferous forests on serpentine soils and forests adjacent to coastal dune systems. Both of these forest types often have less tree cover than more productive soil types, but have dense shrub layers (Slauson and Zielinski 2001, Slauson et al. 2007, Zielinski et al. 2001). Decades of unregulated trapping followed by extensive habitat loss and fragmentation from unregulated

Chapter 1: Introduction

Background

Until recently, the American marten (*Martes americana*) was the only marten species recognized in North America, occurring in boreal forests, montane coniferous forests, and Atlantic and Pacific coastal forests (Gibilisco 1994). However, the Pacific marten (*Martes caurina*) was recently split from the American marten based on genetic and morphological differences (Dawson and Cook 2012). The range of the Pacific marten occurs largely in montane and coastal coniferous forests west of the Rocky Mountain crest, while the range of the American marten occurs to the north and east of the Rocky Mountain crest. The deep genetic split between these two species of martens in North America is thought to have originated from the persistence of marten populations in two disjunct glacial refugia during the most recent glacial period (Dawson and Cook 2012).

The Humboldt marten (*M. c. humboldtensis*), one of the recognized subspecies of the Pacific marten (Grinnell and Dixon 1926), was historically distributed throughout the coastal, fog-influenced forests of the coast redwood (*Sequoia sempervirens* (Lamb. ex D. Don) Endl.) region in California from northwestern Sonoma County northward to the Oregon border (Grinnell et al. 1937) (fig. 1). Ongoing genetic analyses support the conclusion that there is no genetic distinction between martens in the range of the Humboldt marten subspecies in California and the *M. c. caurina* subspecies in the Oregon Coast Range and that these populations represent a single evolutionary unit (Schwartz et al. 2016, Slauson et al. 2009b). Furthermore, based on the combination of nuclear and mitochondrial DNA analyses, coastal California and coastal Oregon martens are different from interior California and interior Oregon martens representing *M. c. sierrae* in the Marble and Trinity Mountains of northern California, *M. c. caurina* in the Cascade Mountains of Oregon, and *M. c. caurina* in the Olympic and Cascade Mountains of Washington. Based on these collective findings, the range of the Humboldt subspecies has been expanded to include the Oregon Coast Range, historically recognized as that of *M. c. caurina* (Schwartz et al. 2016). For these reasons, this assessment and strategy will focus on the collective distribution of the Humboldt subspecies from its historical range in coastal northwestern California and coastal Oregon.

Throughout this assessment and strategy, we have primarily used published studies within the range of the Pacific marten. Where information from the range of that species is limited or absent, we include relevant references from studies within the range of the American marten. However, confusion may arise when describing older studies conducted in the portion of the historically described range

In California, the Humboldt marten has been extirpated from more than 95 percent of its historical range.

and regulated timber harvesting are likely the most important historical factors that caused declines in the distribution and abundance of martens in coastal California and coastal Oregon.

In California, the Humboldt marten has been extirpated from more than 95 percent of its historical range. Until recently, the subspecies was known only from a single population that likely contains fewer than 100 individuals (Slauson et al. 2009a). From 2001 to 2008, occupancy at previously occupied sites in this population declined by 42 percent during a period when minimal timber harvesting occurred in its range (Slauson et al. 2009a). Following the 2008 population assessment, a wildfire burned through approximately 25 percent of this population's range, potentially reducing the population owing to habitat loss or degradation. In 2012, all locations sampled in 2008 were resampled (Slauson 2012). Preliminary occupancy estimates for the 2012 sampling were similar to results from 2008 (Slauson 2012), suggesting that marten occupancy in northern coastal California did not substantially change over that time period. More recently, during 2011–2015, martens were detected at more than 10 sites in two adjacent watersheds of tributaries of the Middle Fork of the Smith River near the California-Oregon border, suggesting that a small population exists there.

In the Oregon Coast Range, martens are known from two apparently disjunct populations in the central and southern portions of the former range (Moriarty et al. 2016, Zielinski et al. 2001). In 2002 and 2017, large wildfires burned through portions of the contemporary distribution of the southern coastal Oregon population, likely resulting in further habitat loss in areas with high burn severity. The four extant marten populations in coastal California and Oregon are separated by distances of 20 to 40 km. Current habitat conditions, degraded by logging, severe wildfire, and urbanization, may render them functionally isolated.

In 2010, the Humboldt marten was petitioned for listing as threatened or endangered under the federal Endangered Species Act (CBD 2010). The U.S. Fish and Wildlife Service published a “substantial” 90-day finding on the petition to list the Humboldt marten on January 12, 2012 (77 FR 1900), but a “not warranted” 12-month finding on April 7, 2015 (80 FR 18741). In 2015, the Humboldt marten was petitioned for listing as threatened or endangered under the California Endangered Species Act (EPIC and CBD 2015). In February 2016, the California Fish and Game Commission accepted the petition and initiated a 1-year status review of the Humboldt marten in California. During this review period, the Humboldt marten is considered a “candidate” for state listing in California, and is afforded all the legal protections provided a formally listed species under California law. In Oregon, the

augmented by other research conducted on Pacific and American marten. Chapter 5 presents the rationale for a conservation strategy and develops a threats assessment based on the information from chapters 2 through 4. Finally, the “Potential Threats to the Humboldt Marten” chapter provides a structure to identify and prioritize specific conservation recommendations.

Goal and Objectives of the Assessment and Strategy

The overall goal of this report is to inform the development of a conservation strategy that will establish self-sustaining, interacting populations of Humboldt martens where possible throughout their historical range. Specific objectives are to:

- Provide a comprehensive review and reference document that describes the biology and ecology of the Humboldt marten (chapters 1 and 4), the biophysical environment in which it exists (chapter 2), and the anthropogenic modifications to that environment (chapter 3).
- Conduct a threats analysis (found in chapter 5) based on the review information in chapters 1 through 4.
- Identify conservation actions that can reduce or eliminate threats (chapter 5).
- Identify key information gaps and research actions to address these information needs (chapter 5).
- Serve as a guiding document for reference by HMCG member organizations (app. 1) to facilitate the implementation of conservation actions to benefit Humboldt marten.

Chapter 2: Biophysical Environment

Physical Environment

We used the generalized historical extent of the distribution of the Humboldt marten in coastal California and coastal Oregon (fig. 1), broad-scale ecological criteria (Ricketts et al. 1999), and natural biophysical features to delineate the Humboldt marten conservation assessment area. From south to north, the assessment area includes three forest ecoregions: northern California coastal forests, the coastal edge of the Klamath-Siskiyou forests, and the central Pacific coastal forests of Oregon (Ricketts et al. 1999). The northern portion of the assessment area is bordered to the east by the nonforested Willamette Valley and in the central and southern portions by the distinctive transition from fog-influenced mesic forest communities to drier interior forest communities. This transition occurs approximately 30 to 40 km from the coast in the Klamath Mountains and 20 to 30 km from the coast farther south in the California Coast Range.

The topography of the assessment area is dominated by steep mountainous terrain dissected by many rivers and creeks. Elevation in the assessment area ranges from sea level to 1524 m. The topographic diversity creates many microenvironments that affect the distribution of vegetation composition and structure owing to elevation, aspect, and weather.

The climate is heavily influenced by proximity to the Pacific Ocean. The combination of Pacific storms in the winter and clouds and coastal fog in the summer produces persistent moist conditions year-round on most of the coastal slope of the assessment area, while inland portions may experience relatively drier summer conditions. Strong west-east gradients in climatic conditions create characteristic shifts in vegetative communities as conditions become drier with increasing distance from the coast. This distance-from-coast gradient is strongest in south coastal Oregon and the California portions of the assessment area, where cool and moist summer conditions become most constricted. Temperatures across the assessment area are relatively mild, with low variation between summer highs (average 15 °C) and winter lows (average 5 °C) (PRISM 2012). As a result of relatively mild winter temperatures, most precipitation falls as rain, with average totals ranging from 100 to 300 cm, generally increasing from south to north in the assessment area. Approximately 90 percent of the area lies below the elevation of persistent snow, which typically occurs above 914 m. Snowpacks usually form only in the northern Oregon Coast Range and along the eastern edge of the assessment area in northern California and southern coastal Oregon. Summers are warm but remain moist

owing to the presence of clouds and fog. This summer moisture strongly influences the structure and composition of coastal forests.

Plant Communities and Natural Disturbance

The assessment area is characterized by some of the most productive forests in the world. In unmanaged late-seral stages, these forests are typically composed of long-lived, large trees, multilayered canopy structures, substantial standing and down large woody debris, and abundant ferns, herbs, and shrubs on the forest floor (Chappell et al. 2001, DellaSala et al. 2011, Sawyer 2007, Sawyer et al. 2000b). Assessment area forests are largely coniferous, typically dominated by redwood and Douglas-fir in California and by Douglas-fir, western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and Sitka spruce (*Picea sitchensis* (Bong.) Carrière) in Oregon (Ricketts et al. 1999, Sawyer 2007). Subdominant conifers include western redcedar (*Thuja plicata* Donn ex D. Don), Port Orford cedar (*Chamaecyparis lawsoniana* (A. Murray bis) Parl.), and grand fir (*Abies grandis* (Douglas ex D. Don) Lindl.), with sugar pine (*Pinus lambertiana* Douglas) and white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) at higher elevations (Chappell et al. 2001, Sawyer 2007). Hardwood-dominated stands in the assessment area are uncommon, but hardwoods such as tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) P.S. Manos, C.H. Cannon, & S.H. Oh), golden chinquapin (*Chrysolepis chrysophylla* Douglas ex Hook.) Hjelmqvist), and Pacific madrone (*Arbutus menziesii* Pursh) are common canopy subdominants. In some near-coast locations or postlogging sites, red alder (*Alnus rubra* Bong.) can be an early-successional overstory dominant. Riparian forests featuring broadleaf species such as red alder, black cottonwood (*Populus balsamifera* L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook.) Brayshaw), and bigleaf maple (*Acer macrophyllum* Pursh), and mesic shrub species such as vine maple (*A. circinatum* Pursh), often are distinct within the conifer-dominated forests.

Dense herbaceous or shrub layers are characteristic structural components of the forest floor in unmanaged stands in the assessment area. Species presence and dominance is shaped largely by the combination of soil nutrients and moisture, with herbaceous species such as western sword fern (*Polystichum munitum* (Kaulf.) C. Presl) dominating on nitrogen-rich or very moist sites, and evergreen shrubs such as Pacific rhododendron (*Rhododendron macrophyllum* D. Don ex G. Don) and salal (*Gaultheria shallon* Pursh) dominating on nutrient-poor or drier sites (Chappell and Kagan 2001). Other dominant or codominant understory shrub species include evergreen huckleberry (*Vaccinium ovatum* Pursh), salmonberry (*Rubus spectabilis* Pursh), red huckleberry (*V. parvifolium* Sm.), and in serpentine habitats (see description below), shrub form tanoak (*N. densiflorus* var. *echinoides* (R.Br. ter) P.S.

Manos, C.H. Cannon & S.H. Oh), and huckleberry oak (*Quercus vacciniifolia* Kellogg) (Chappell et al. 2001, Jimerson et al. 1995, Sawyer et al. 2000b). Many of the dominant shrub species are adapted to fire by having lignotubers (basal swellings at the interface between the roots and shoots below the soil surface), allowing these species to quickly sprout after fire and thus maintain site dominance (Agee 1993).

Two other forest habitats of particular relevance to martens include coastal serpentine habitats and dune forest communities on coastal terraces. Martens have been detected in these habitat types recently; however, these types have limited distributions compared to the more extensive dominant coastal forest types that supported the majority of the historical marten distribution. We use the term “serpentine” to refer to the environment influenced by the unique chemical composition of ultramafic rocks, serpentine, and serpentinized peridotite, and the resulting plant community structure and species composition it supports (Harrison and Rajakaruna 2011, Jimerson et al. 1995).

Forests in serpentine habitats are typically open and rocky with stunted trees that contrast sharply with the dense, rapidly growing stands on more productive, nonserpentine soils that surround these sites (Jimerson et al. 1995). On the extreme coastal edge of the distribution of serpentine habitats within the assessment area, increased moisture and summer fog help to support dense, spatially extensive shrub layers. Martens have been found in this type of serpentine habitat in both south-coastal Oregon and north-coastal California portions of the assessment area (see “Multiscale Habitat Use” in the “Biological Information” chapter), but not in the more extensive interior serpentine habitats that are more open owing to the low amount of shrub cover. The specific serpentine plant communities used by martens include a variety of coniferous trees such as Douglas-fir, sugar pine, lodgepole pine (*Pinus contorta* Douglas ex Loudon), western white pine (*P. monticola* Rydb.), Jeffrey pine (*P. jeffreyi* Balf.), knobcone pine (*P. attenuata* Lemmon), and Port Orford cedar, and are dominated by mast-producing shrubs such as shrub form tanoak, huckleberry oak, and red huckleberry (Jimerson et al. 1995, Slauson 2003). Like the shrub community used by martens on more productive soil types, the shrub community in serpentine habitats is composed of long-lived, mast-producing species that maintain site dominance, rather than early-seral shrub communities composed of species such as *Ceanothus* sp. Nutt, which only dominate for relatively short periods after disturbances.

We use the term “coastal dune forest communities” to describe the forests on stabilized dune terraces that are typically dominated by shore pine (*P. contorta* Douglas ex Loudon var. *contorta*; a coastal form of lodgepole pine), and in some

areas codominated by Sitka spruce. The understory of these forest communities is typically dominated by salal and evergreen huckleberry (Chappell et al. 2001). In the assessment area, these sites are primarily in coastal Oregon.

Natural Disturbance

In the assessment area, natural disturbance forces affect the composition and structural characteristics of the forest communities at multiple spatial scales. These include fire, windthrow, insects, disease, and mass wasting events such as landslides. Fire is the major coarse-scale disturbance force in all but the wettest coastal forests, where windthrow is the major source of natural disturbance. A fire regime is the product of the climate, ignition frequency, and the characteristic pattern in which fire interacts with the topography and vegetation structure within any region (Agee 1993). Fire regimes are typically defined by the following attributes: temporal (seasonality and fire return interval), spatial (fire size and burn complexity), and magnitude (intensity, severity, fire type) (Sugihara et al. 2006). In general, short fire return intervals are indicated by the presence of multiple fire scars within old living trees or recently cut stumps. Many trees survive the low-intensity fires characteristic of shorter return intervals. In contrast, long fire return intervals are characterized by rare but destructive fires; such past fires are sometimes indicated by large stands of old trees of very similar age that regenerated together after a catastrophic event.

In the following discussion, we describe the prehistoric fire regimes that existed in the assessment area prior to their interruption following Euro-American settlement. The prehistoric fire regimes included strong influences from many centuries of American Indian anthropogenic burning, which are included in this discussion of “natural” disturbance, as well as in the “Human Modifications to the Environment” chapter. The purpose of this discussion is to provide perspective on the forests present in the assessment area today, which to varying degrees still reflect influences from the prehistoric period.

As elsewhere, ignitions in the assessment area occur from either lightning strikes or anthropogenic sources. Lightning strikes are fewest in northern and southern portions of the assessment area and greatest in the western edge of the Klamath-Siskiyou ecoregion, where the driest conditions and the highest mountains occur (Morris 1934, van Wagtenonk and Cayan 2008).

In coastal portions of the assessment area, conditions that promote ignition and spread of fire are moderated by high winter precipitation and by fog, clouds, and moderate temperatures during summer (reviewed in Lorimer et al. 2009). Strong ocean-to-inland, and to a lesser degree, north-to-south gradients in these

climate-driven moisture conditions are evident across the assessment area. These regional gradients result in nonanthropogenic fires occurring more frequently with increasing distance from the coast and farther south in the assessment area (Oneal et al. 2006, Sawyer et al. 2000a). At finer scales, topographic characteristics such as slope position and aspect strongly affect fire frequency and severity (Oneal et al. 2006). From north to south, the inland extent of moist maritime conditions declines and becomes highly dendritic, pushing farther inland primarily within coastally oriented watersheds.

Lightning strikes in the redwood forests of the Northern California Coast ecoregion occur at only 15 to 23 percent of the frequency observed in more interior sites in the Klamath Mountains and Sierra Nevada (van Wagtendonk and Cayan 2008). Furthermore, lightning strikes in coastal forests are less likely to ignite fuels owing to the presence of coastal fog during the months of peak strike activity (reviewed in Lorimer et al. 2009).

In the northern and central Oregon portions of the assessment area, the fire regime is classified as stand replacing with very infrequent (i.e., >200 years) return interval in the north, transitioning into a low and mixed severity with 35- to 200-year return intervals in the central region (USDI GS 2012). Within these areas, the fire regime differs by forest type. Moist Sitka spruce forests exist in the near coastal zone where climatic conditions limit both the frequency and intensity of naturally occurring fires (Agee 1993). Fires in Sitka spruce forests were very rare and burned under rare weather conditions where fires were driven into the coastal zone by dry winds from the interior (Agee 1993). Many fires spreading from interior western hemlock forests were naturally extinguished upon entering Sitka spruce forests (Agee 1993).

In moist western hemlock forests of coastal Oregon, extensive stand-destroying fires are part of the historical record (Agee 1993). Although large blocks of single-age cohort forests occurred in the northern Oregon Coast Range as a result of large and severe fires, the fire regime in the central Oregon Coast Range is a mix of high- and low-severity fires with fairly long return intervals averaging >250 years (Impara 1997). Although there are some accounts of American Indians using fire in the central and northern Oregon portions of the assessment area, Agee (1993) found little evidence to suggest that their influence represented a major effect on the fire regimes found there. Conclusions from studies using fire scar and age class analysis generally agree in this portion of the assessment area (e.g., Impara 1997).

In the south coastal Oregon and California portions of the assessment area, the fire regime shifts to a mix of low- and mixed-severity fires with 0- to 35-year and 35- to 200-year frequencies (USDI GS 2012). Paradoxically, the most frequent fires apparently occurred throughout the Redwood Region, including near-coast sites

and along drainage bottoms where climatic and ignition patterns rarely support the natural occurrence of fire. Although fire scar studies report frequent fires (e.g., <26 years) (Norman 2007) in the Redwood Region, existing stand structures suggest infrequent high-severity events (e.g., >500 years) (Veirs 1982). This mismatch between fire ignition rates and fire frequencies indicate a large influence of regular anthropogenic fire in these areas.

Lorimer et al. (2009) reviewed fire history studies conducted throughout the Redwood Region of the assessment area and concluded that the majority of pre-settlement fires were likely of American Indian origin and therefore that estimating the nonanthropogenic occurrence of fire was not likely possible from fire scar analysis. Annual and near-annual burning by American Indians to keep village sites and travel routes clear and to improve resources such as acorn crops, forage for game, and plants for basketmaking materials was widespread, with more frequent burning associated with forest conditions with higher moisture levels (Anderson 2006, Lake 2007, Stuart and Stephens 2006, Vale 2002). Trends of fire frequency increasing with drier conditions along both west-east and north-south gradients are, however, present in fire scar data for the Redwood Region and likely represent the overall variation in fire frequency (Lorimer et al. 2009). Agee (1993) characterized the Redwood Region as having a moderate-severity fire regime, owing to its ability to resist all but the most extreme fire events. Nonanthropogenic fire frequency most likely differs along moisture and climatic gradients consistent with centuries-long return intervals in the nearest coastal locations, to several decades in locations where redwood forests border more fire-prone habitats.

In the interior areas of the California and southern Oregon portions of the assessment area, mesic coastal forest types transition into largely Douglas-fir-dominated forest types. In these forest types, both fire scar and age class studies corroborate low- and mixed-severity fire regimes with 35- to 200-year frequencies. A significant influence from American Indian burning is also evident in these forests (Lake 2007, Lewis 1993). The assessment area includes the most mesic portion of the Douglas-fir forest types (which extend farther inland toward more xeric conditions), including stands that are on the longer end of the range of fire frequency for this type. However, geologic and topographic diversity within the Klamath-Siskiyou Mountains have produced substantial variation in fire frequencies and burn severities, precluding generalizations across the region (Agee 1993). For instance, the presence of fire-dependent species such as lodgepole pine and knobcone pine along serpentine-soil-dominated ridges suggests along serpentine soil dominated ridges that fire frequency may be very complex and site specific across this portion of the assessment area.

Windthrow is another important disturbance factor that may complement other disturbances such as fire and disease, or may represent the dominant disturbance factor in mesic forest types where fire is rare (e.g., Sitka spruce forests) (Ruth and Harris 1979). Windthrow is typically recognized as a relatively fine-scale disturbance factor, producing single and small clusters of partial or entire tree breakage and uprooting, respectively. However, topographic position can play a role in uncommon large-scale windthrow events that create uneven-age structure in coastal forests over many decades (Harcombe et al. 2004). Severe windthrow events are episodic but can dramatically alter forest structure and composition. Windthrow can also increase structural complexity in trees by snapping tops and stimulating regrowth of multiple tops that provide unique habitats for flora and fauna (Sillett and Van Pelt 2007). Limb and leader breakage from windthrow can also allow for fungal pathogens and insects to attack trees, starting the process of cavity and snag creation.

Insects, disease, and landslides typically foster small-scale disturbances at the level of individual trees or small patches of trees. However, the pathogens that cause Port Orford cedar root rot (*Phytophthora lateralis*) and sudden oak death (*Phytophthora ramorum*), two recently established nonnative disease agents, have the potential to greatly alter the composition and function of forests within the assessment area (Hansen et al. 2000, Rizzo and Garbelotto 2003). Port Orford cedar root rot affects only a single species, but causes high mortality rates (USDA FS 2006). Sudden oak death affects many oak species and has the potential to result in large-scale mortality of species such as tanoak, chinquapin, and shrub oaks that are common components of marten habitat (see the “Biological Information” chapter) (USDA FS 2006). The variety of oak species in forests of the assessment area provide key resources for martens and their prey in the form of annual mast crops and cavity formation that provide resting and denning locations.

Implications for Conservation

- The assessment area is biophysically diverse and includes substantial variation in dominant forest types and their relationships with key disturbance factors. Conservation actions and measures must be developed to be applicable within the context of this variability.
- Prehistoric fire regimes shaped the forest types present across the assessment area. Fire frequency and severity are dependent on the site-specific conditions present in each forest type. Nonanthropogenic fire frequency varies along dominant gradients in summer moisture and temperatures, increasing in frequency both from north to south and west to east across the

assessment area. Burning by American Indians was apparently the primary source of ignition in some areas, strongly increasing the fire return rate in these areas. Managers seeking to use the historical fire regime as a template for guiding current management should evaluate the sources of fire return interval data to identify sites representing anthropogenic and nonanthropogenic fire histories, and clearly identify where management for anthropogenic fire histories may be desirable.

Chapter 3: Human Modifications to the Environment

American Indian Use of Martens

Historically, martens were trapped and their skins used in ceremonial regalia by the Yurok Tribe of northern coastal California (K. Slauson, pers. obs., 2002) and tribes in coastal Oregon (Jacobs 1934). However, their relatively low prominence among other regalia and long use when incorporated into regalia suggests that martens were not trapped for these purposes at levels that would significantly affect populations. Tribes located on the eastern edge of the assessment area do not feature martens in regalia, but nearby tribes such as the Hoopa Valley Tribe in California do prominently feature fishers (*Pekania pennanti*) (Higley 2008).

American Indian Use of Fire

American Indian tribes used fire for cultural fire purposes throughout the assessment area (Lake 2007). The use of fire by American Indians differed from nonanthropogenic fire regimes in five key ways: seasonality, frequency, extent, site, and outcome (Kimmerer and Lake 2001). Notably, Kimmerer and Lake (2001) stated “scholars of aboriginal fire agree that anthropogenic fire far exceeded the frequency of natural lightning strikes.” Within the assessment area, the shortest reported fire return interval, 7 years (Veirs 1982), is closest to known village sites; fire return intervals increased with distances from such locations (Norman 2007). American Indians used frequency of burning and season of burning to minimize the spatial extent of fires and to achieve the intended outcomes over the desired area (Lake 2007). The cultural fire regime was managed to meet objectives at a variety of spatial scales, including the site-specific, resource patch, and broadcast burning of larger areas (Lake 2007). In locations that were routinely managed by tribes using fire, the nonanthropogenic fire regime was overridden by the anthropogenic fire regime. Therefore, the reconstruction of fire history from fire scar studies requires that the landscape context and degree of nonanthropogenic influence be taken into account for each study location. For example, fire scar studies that have reported the shortest fire-return intervals in the northern Redwood Region are also those in proximity to American Indian village sites; however, village sites represent a small proportion of the historical landscape. Creating regional mean fire return intervals by simply averaging the results across studies, without weighting them by their relative historical spatial influence, may result in negatively biased estimates. For instance, the unweighted mean approach was used by Safford et al. (2010) to produce a mean estimate of 23 years for the redwood forest type—a return interval clearly uncharacteristic for nonanthropogenic ignition regime in this climate, especially in the northern range of the redwoods.

In locations that were routinely managed by tribes using fire, the nonanthropogenic fire regime was overridden by the anthropogenic fire regime.

Historical and Contemporary Use and Management of Natural Resources

Trapping of martens for the fur trade—

By the early 1900s, annual harvest totals of martens in the assessment area were already in decline, signaling stress on populations from trapping.

The first major impact of the arrival of Americans of European ancestry on martens was the fur trade. Trappers from British companies on the Columbia River entered the Oregon Coast Range in the early 1820s, focusing on beaver and otter, but also taking “small furs” (Dillon 1975). By the late 1800s and early 1900s, significant trapping efforts were well underway (Anonymous 1914, Grinnell et al. 1937). By the early 1900s, annual harvest totals of martens in the assessment area were already in decline, signaling stress on populations from trapping (Dixon 1925, Zielinski et al. 2001). Accounts of individual trappers taking 35 and 50 martens during single winters in localized areas within the California portion of the assessment area (Grinnell et al. 1937) suggest the historical abundance of the Humboldt marten and the impact of individual trappers on marten populations. The sharp decline in annual harvest rates caused Dixon (1925) to call for the closing of the trapping season on martens in California in 1925 for fear of their extirpation. Declining trapping harvests led to the closure of the marten trapping season in extreme northwestern California in 1946 (Zielinski et al. 2001). The trapping season for martens within the entire California portion of the assessment area was closed in 1954.

Trapping records for the Oregon portion of the assessment area peaked in the 1940s and did not exceed 15 percent of the 1940s levels thereafter (Zielinski et al. 2001). Martens are still legally trapped in the Oregon portion of the assessment area. At about the same time the trapping season was closed in California and the peak trapping harvest occurred in coastal Oregon, the era of large-scale clearcut logging of coastal old-growth forests was beginning (Haynes 2001, see the “Habitat Loss and Conversion From Timber Harvest” section below), compounding the negative effects on martens.

Alteration of Natural Fire Regimes

Contemporary changes to the fire regimes within the assessment area include elimination, suppression, or management of most natural and anthropogenic ignitions. Long-established American Indian burning practices have disappeared. Currently, burning for grazing, fuel reduction, and forestry site preparation is carried out under prescribed conditions, and most wildfires are suppressed as soon as possible. Fire suppression has strongly affected the structure and function of forest ecosystems in more interior forest types, such as mixed-conifer forests in the mid elevations of the Sierra Nevada Mountains (Miller et al. 2009). However, in portions of the assessment area with summer fog, fire suppression appears to have had

little effect on the structure and composition of the dominant forest types, and has not caused an increase in high-severity fire relative to the historical patterns (Miller et al. 2012, Odion et al. 2004).

Miller et al. (2012), in a study that encompassed four national forests, including the Six Rivers National Forest, did not detect a change in the trend of fire severity from 1910 through 2008, but found that other parameters such as fire frequency, size, and total acres burned had increased. They reported that in forest types largely inland from the assessment area, high-severity fire most frequently occurred in areas dominated by small-diameter trees. In forest types where fire-return intervals are centuries long, the period of fire suppression may not yet have been long enough to accumulate such effects (e.g., Oneal et al. 2006, Veirs 1982). Where fire-return intervals are shorter, such as a few decades, forest structural change and subsequent wildfires have not produced burn conditions outside those expected in unmanaged stands based on the patterns of presuppression burning (Miller et al. 2012, Odion et al. 2004). Our review suggests that the prevailing notion that fire suppression has moved forests out of their natural range of variability, increasing their susceptibility to increased fire severity, applies more strongly to interior and southern portions of the assessment area than to near-coast forest types that receive summer fog.

Uncertainties regarding the degree of historical wildfire, sources of such fires, degree of change in forest structure owing to suppression efforts, and localized differences in fire-mediating conditions such as summer fog, create challenges for management. Evaluations of changes in forest structure and susceptibility to higher severity fire, and actions intended to reduce the risk of high-severity fire, will have to be made cautiously based on site-specific information. However, if future changes in climatic conditions result in drier and warmer conditions, an increase in fire severity and intensity may result, especially in the most inland portions of the assessment area.

In the assessment area, the most dramatic change to the fire regime has been the loss of American Indian burning practices from the California coastal ecoregion and the western edge of the Klamath-Siskiyou forest ecoregion where it was commonly practiced historically (Lake 2007). Based on the characteristics of the climate and nonanthropogenic fire ignition frequency in the assessment area, it is most likely that American Indian burning dramatically decreased the nonanthropogenic fire return intervals where it was practiced (Lorimer et al. 2009). The shortest fire return intervals (<20 years) in mesic forest types (e.g., redwood) in the southern portion of the assessment area are in proximity to village sites (e.g., Norman 2007,

The prevailing notion that fire suppression has moved forests out of their natural range of variability, increasing their susceptibility to increased fire severity, applies more strongly to interior and southern portions of the assessment area than to near-coast forest types that receive summer fog.

Before the era of commercial timber harvesting, vegetation within the assessment area was predominantly composed of old-growth coniferous forest.

Veirs 1982) and fire return intervals increase greatly with the distance from village sites (e.g., Veirs 1982). This suggests that fire return interval data are best interpreted in the context of gradients that span environmental, ocean-inland distances, and anthropogenic activity, and distance from village and key resource sites. Simple averages of point estimates of fire return interval studies (e.g., Safford et al. 2010, USDI GS 2012) are likely to be misleading until there is a better understanding of the extent to which environmental and anthropogenic gradients affected historical fire regimes in the southern portion of the assessment area.

Habitat Loss and Conversion From Timber Harvest

Before the era of commercial timber harvesting, vegetation within the assessment area was predominantly composed of old-growth coniferous forest. Estimates of the historical amount of old growth in coastal forests differ depending on the definition of old growth and the extent of the area examined, but most estimates of the percentage of area in old-growth forest conditions at the time of European colonization were >75 percent for the coastal California region, >50 percent for the Klamath-Siskiyou region (Strittholt et al. 2006), and 40 to 85 percent in the Oregon Coast Range (e.g., Ripple 1994, Strittholt et al. 2006, Teensma et al. 1991).

The forests of the assessment area were largely accessible to early logging methods by the late 1800s and early 1900s, with wide-scale harvesting increasing after World War II. As a result, most of the old-growth forests in the assessment area have been logged (Bolsinger and Waddell 1993), causing coastal old-growth forests to be considered one of the most heavily affected terrestrial habitats in western North America (Ricketts et al. 1999). For example, Save the Redwoods League (2015) estimated that approximately 5 percent of the original old-growth coast redwood forest remains across the 809 000-ha range of that species (which is almost entirely in California). The Oregon Coast Range is estimated to contain <10 percent of the historical amount of old-growth (Bolsinger and Waddell 1993, Ohmann and Spies 1998), with the highest amount remaining on the Siuslaw National Forest. Modeling landscape-scale growth and fire simulations, Wimberly et al. (2000) estimated that at any one time during the past 3,000 years, between 25 and 75 percent of the Oregon Coast Range supported old-growth forests under the natural fire regime.

The spatial distribution of old-growth forest has also changed over the past 200 years. In the Oregon Coast Range, old-growth patches were historically large (210 000 to 850 000 ha), but have been reduced to a maximum of 647 ha today (Wimberly 2002, Wimberly et al. 2004). Furthermore, old-growth forest patches were more connected historically, with most forest patches >200 years old located within

1 km of another old-growth patch, whereas today old-growth patches are much more isolated from the nearest remnant patch (Wimberly et al. 2004).

Current Condition and Land Use of Assessment Area

Land ownership in the assessment area is composed of private industrial timberlands (>50 percent), U.S. Forest Service (USFS) (20 percent), Bureau of Land Management (BLM) (10 percent), state and national parks (<5 percent), state forests (<10 percent), and small private and tribal lands (<5 percent) (fig. 2). On industrial timberlands, clearcut logging, short-rotation silviculture, removal of late-seral structure and hardwoods, and road building have produced forests with highly altered structures and compositions. Managed regenerating stands often lack key habitat elements used by martens, especially suitable resting and denning structures in large, standing, live and dead trees, and dense ericaceous shrub cover (Slauson and Zielinski 2007, Slauson et al. 2010). On industrial timberlands, older regenerating stands that are developing such conditions may be scheduled for harvest in future decades, unless they are part of other conservation agreements for other wildlife or fish species.

Logging on USFS and BLM lands was not as prevalent historically as on private lands, and in recent decades has primarily been confined to thinning and management of older forest plantations. USFS and BLM lands in California and Oregon include more than 202 000 ha of wilderness areas within the assessment area. In the majority of these areas, the primary human influence may be stand conditions reflecting lack of wildfire, but >25 percent of these areas have burned in the past two decades. Redwood National and State Parks total more than 72 000 ha in the assessment area, with approximately one-third of the area composed of old-growth forest. Forests in state and national parks, and some tribal lands, are not subject to harvest, except where younger stands logged by previous owners are being thinned and managed to develop old-growth characteristics.

In recent years, federal and state land management agencies in the assessment area have focused on forest restoration and fuels management. These efforts have included management of young stands in previously logged areas to stimulate stand growth toward mature conditions, and thinning of understory fuels in older stands to reduce the likelihood of catastrophic fire. Because of limited budgets, these efforts have treated a small percentage of the areas where such actions would be appropriate.

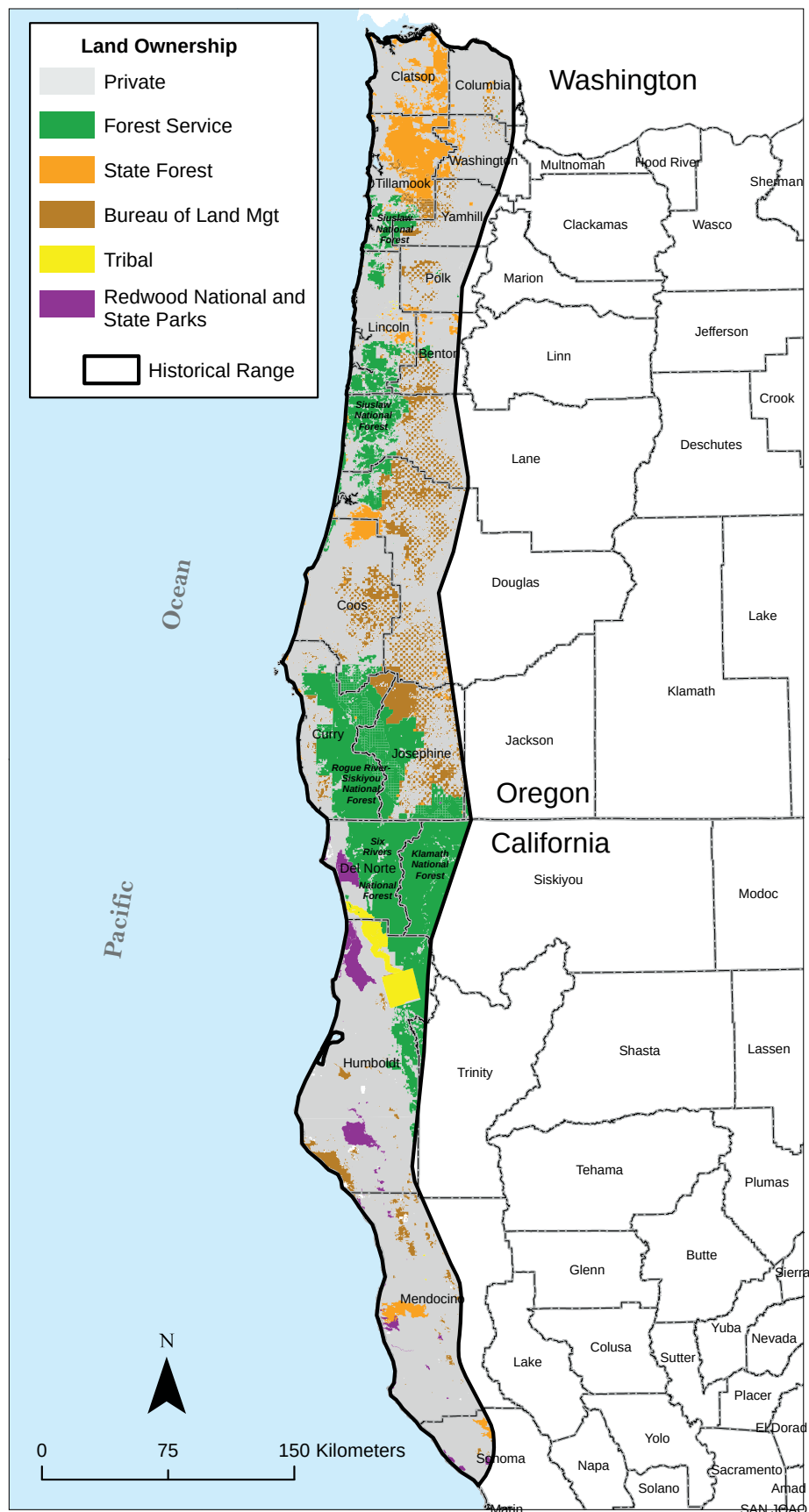


Figure 2—Land ownership within the historical range of the Humboldt marten (*Martes caurina humboldtensis*) in coastal California and coastal Oregon.

Predator Control

Predator control using a variety of direct and indirect methods was historically commonplace in the Western States to improve game populations and protect livestock. Although martens may not have been targeted directly, the methods used to poison target predators were often not specific to the target species. Two former methods, poisoning carcasses of ungulates and aerial broadcasting of poisoned baits, were capable of killing martens. On the Olympic Peninsula of Washington in the early 1900s, dead martens and fishers were observed in the vicinity of ungulate carcasses that had been shot and laced with poison baits (B. Adamire, pers. comm., in Zielinski et al. 2001). Records of the distribution and intensities of these activities are difficult to obtain and their historical prevalence in the assessment area is unknown. Intentional poisoning as a means of predator control largely ceased before the 1970s.

More recently, widespread use of rodenticides and other toxic chemicals at illegal marijuana cultivation sites has emerged as a threat to Pacific martens. In California, residues of anticoagulant rodenticides were found in >85 percent of dead fishers tested for toxicant exposure, and several fishers have died from acute rodenticide poisoning on the Hoopa Valley Indian Reservation, located on the southeastern edge of the assessment area (Gabriel et al. 2012b, Gabriel et al. 2015). Although predation was the dominant source of mortality for fishers throughout California (70 percent compared to 10 percent for toxicants), a greater proportion of the fisher mortalities in northern California were attributed to toxicants and fewer to predation as compared to the Sierra Nevada population of fishers (Gabriel et al. 2015). Given the similarity in foraging and diet composition between fishers and martens, and the widespread occurrence of illegal marijuana cultivation in the assessment area, rodenticide exposure could be a serious threat to the persistence and recovery of Humboldt marten populations in the portions of the range (e.g., mainly California) where illegal marijuana cultivation occurs. As of 2014, an ongoing study in California had detected rodenticides in one of six (17 percent) dead Humboldt martens tested (Slauson et al. 2014).

Climate Change in the Assessment Area

The assessment area includes the southern terminus of temperate rainforests of the North American continent. These forests are dependent on a suite of climatic conditions that create moist conditions throughout much of the year (DellaSala et al. 2011). Overall, climatic conditions that support mesic coastal forests extend farther inland in Oregon and are limited to near the coast in the southern Oregon

and California portions of the assessment area. Global climate change is expected to increase average temperatures across the assessment area in coming decades; however, the exact magnitude of this change is still in question and depends in large part on the continued rate of global carbon emissions (DellaSala 2013).

Predictions for changes to future precipitation levels differ for the assessment area (PRBO 2011). Climate projections suggest that drier conditions will occur closer to the coast in the future, resulting in a narrower extent of coastal forest, and loss and fragmentation of coastal forests at their southern extent in California. Changes have already been observed in a key element of precipitation: summer fog frequency has been declining over the past century across the California portion of the assessment area (Johnstone and Dawson 2010). This trend could reduce the inland and southern extent of coastal forest conditions such as the distribution of dense shrub layers that are an important component of marten habitat. However, other authors reviewed by PRBO (2011) speculated that fog may increase as a result of an increasing temperature differential between land and ocean.

Under moderate emissions scenarios, within 50 years, current bioclimatic conditions are projected to occur reliably only in northern Humboldt and Del Norte Counties in the current northern extent of the coast redwood's range (DellaSala 2013). In the Oregon portion of the assessment area, contractions of the bioclimatic conditions supporting coastal forests are projected to be greatest in the south coastal region, south of the Rogue River. Here, conditions supporting coastal forests will likely become increasingly limited to a more narrow inland distribution within 50 years (DellaSala 2013). Projections for impacts of climate change on forests in the northern portion of coastal Oregon are less severe.

Implications for Conservation

- The magnitude of loss and fragmentation of late-successional and old-growth forest habitat in the assessment area limits the locations where short-term conservation actions can benefit marten population persistence and recovery.
- Most remaining late-successional and old-growth landscape-scale restoration of functional connectivity among areas currently suitable as habitat for martens is an important conservation consideration and will require cooperation from both public and private land managers.
- Fire is an important natural disturbance process and accurately understanding its role in creating and maintaining forest structural and compositional conditions is critical for informing the management of natural or desired

conditions. In the California and southern Oregon portions of the assessment area, evidence of fire history can include both natural and cultural fire regimes. Cultural fire regimes greatly increased fire frequencies to produce desired resource conditions in specific areas, but these effects had limited spatial distributions within the assessment area. Application of reconstructed fire history data to guide management of existing conditions will require the careful evaluation of the role cultural fire regimes played in the fire history data being used to avoid overrepresenting the influence of cultural burning had across the landscapes of the assessment area. The evaluation of the historical role fire had on creating site-specific conditions will require characterization of the frequency and the extent to which cultural versus natural fire regimes occurred at the specific locations being considered for management.

- Alteration of the natural fire regime in much of the assessment area has not resulted in conditions promoting an increase in fire severity on account of excessive fuels buildup that has occurred in more inland areas with more frequent fire return intervals. Recent fires in and adjacent to the assessment area have increased in size compared to historical fires, with most high-severity portions of fires occurring in young, largely managed stands. The trend toward larger fire sizes will likely put more marten habitat at risk in the short term. Even fires of moderate intensity may have short-term negative impacts of reducing the important shrub layer (see the “Stand-Scale Habitat Use” section).
- Protection of marten habitat elements may at times appear to be at odds with other management objectives. Habitat elements that confer suitability for marten are often also targeted to reduce the risk of high-intensity or large fires. Management to improve habitat conditions for martens and other species, while reducing the risk of catastrophic wildfire, will have to consider the tradeoffs between these objectives where they are at odds for specific habitat features. Note specifically the challenge of maintaining or regenerating a shrub layer when carrying out understory thinning to reduce fuel density. Creative planning and perhaps new science can be applied to explore the tradeoffs of the possible long-term benefit of effective fuels treatments against their short-term negative effects on key habitat features.
- The objectives of reducing the risk of severe fire and maintaining marten habitat elements are not mutually exclusive over the long term; in fact, the persistence of a sufficient amount of suitable habitat to support marten populations will be dependent, in part, on reducing the impacts of high-severity

fire. Managers can strive to incorporate known elements of marten habitat as management objectives at various spatial and temporal scales, while improving overall forest resilience to severe wildfire and climate change. Reducing the risk of severe wildfire through habitat modification in certain areas may improve the persistence of marten habitat in neighboring areas or across the landscape as a whole. Late-successional and old-growth forest habitat in the assessment area severely limits the locations where short-term conservation actions can benefit marten population persistence and recovery.

- Most remaining late-successional forest occurs on public lands, but land ownership in the assessment area is dominated by private industrial timberlands. On private lands, the remaining small remnants of old forest are patchily distributed.
- The illegal use of rodenticides and other toxic chemicals in marijuana cultivation poses a serious threat to marten populations in the assessment area. Environmental conditions sought by illegal marijuana growers, such as road access, small streams, and recently harvested timber sites, are widespread in currently occupied marten habitat in California and southern Oregon.
- The projected effects of climate change will present challenges to the restoration of habitat and populations, particularly in the southern portion of the assessment area. It appears that the overall extent of favorable conditions will be reduced, along with connectivity between areas where climate is favorable for habitat. This emphasizes the value of conservation actions that restore habitat in the remaining areas with the largest amounts of suitable habitat that have the potential to support meaningful populations, reduce threats in such areas, and ensure that these areas are connected to the greatest degree feasible.

Chapter 4: Biological Information

In this section we review existing biological knowledge of the Humboldt marten. As described above, early information primarily came from trapping records and the collection of museum specimens. Detection surveys, some incorporating vegetation analysis, were underway in the 1990s (Zielinski et al. 2001). Detailed field research on the Humboldt marten only began in 2000; thus, many aspects of its biology and ecology have not been studied. In this assessment, we have used all published and unpublished data available up to 2016 from within the range of the Humboldt marten. Where information gaps existed, we drew upon published information from outside the range of the Humboldt marten that best characterized aspects of its biology that are consistent across the range of the species. We used unpublished data from both inside and outside the range of the Humboldt marten sparingly and only to fill gaps in the published literature.

Description and Taxonomy

North American martens are characterized by the typical long and narrow mustelid body type, overall brown pelage with distinctive gular (throat) coloration varying from orange to yellow to cream, large and distinctly triangular ears, and a bushy tail that is proportionally equivalent to about 75 percent of the body length (Clark et al. 1987, Powell et al. 2003) (fig. 3). The combination of these characteristics can be used to distinguish martens from other mustelids, including the larger fisher, which usually appears black in the field, with well-rounded ears and a comparatively longer tail that is proportionally equivalent to >80 percent of body length (Powell et al. 2003) (fig. 3). Martens can be distinguished from the similar-size American mink (*Neovison vison*), which can have either dark or medium brown pelage, by the mink's comparatively small and rounded ears, and shorter, less bushy tail (Larivière 1999) (fig. 3). The long-tailed weasel (*Mustela frenata*), with a smaller body size and comparatively more rounded ears than martens, shares the overall brown pelage and includes yellow-orange gular coloration but often has white, yellow, or black pelage coloration that extends onto the rostrum, between the eyes, and on the sides of the face (King and Powell 2006). In addition, the long-tailed weasel has a much less bushy tail and a more clearly defined black terminal tip (fig. 3).

Among the American and Pacific marten species, as many as 14 subspecies have been proposed based on variation in morphological characteristics (Hall 1981). The merits of these subspecies have been the subject of considerable debate owing to the interpretation of patterns of morphological variation observed among subspecies (Dillon 1961, Hagmeier 1958). Recent phylogenetic studies have found little

Diagnostic photos



Marten.



Fisher.



Mink.



Long-tailed weasel.

U.S. Forest Service

U.S. Forest Service

Remote camera photo



Marten.



Fisher.



Mink.



Long-tailed weasel.

K. Slauson

U.S. Forest Service

Figure 3—Comparison of photographs of Humboldt martens (*Martes caurina humboldtensis*) from the similar fisher (*Pekania pennanti*), American mink (*Neovision vison*), and long-tailed weasel (*Mustela frenata*). The upper panel includes diagnostic photos. The lower panel includes typical photos from remote cameras for martens, fishers, and mink, where identification is best made using the combination of relative tail length-to-body length ratio, ear morphology, and overall pelage coloration.

genetic variation across the continuous mainland distribution of the American marten (Dawson and Cook 2012, Graham and Graham 1994, Kyle and Strobeck 2003), with the exception of the Newfoundland marten (*M. americana atrata*) (McGowan et al. 1999), suggesting that the American marten recently expanded from a single glacial refugium in eastern North America.

In contrast, Dawson (2008) found significant geographic variation within the Pacific marten, consistent with patterns of genetic variation reported for other species that expanded from multiple glacial refugia during the Holocene (Hewitt 1996, Lessa et al. 2003). These phylogeographic findings suggest that subspecific designations for the Pacific marten most likely reflect the distribution of populations and geographic variation resulting from isolation in disjunct forest refugia during the last glaciations (Slauson et al. 2009b). Throughout this section, we adopt the new species-level nomenclature, but maintain the use of subspecific epithets as previously described (e.g., Hall 1981).

The Humboldt marten (*M. caurina humboldtensis*) and the Sierra marten (*M. c. sierrae*) are now recognized as the two subspecies of Pacific marten in California (Zielinski and Slauson, in press). In Oregon, two subspecies of martens have been recognized historically, including *M. c. caurina* of the Coast Range and Cascade Mountains, and *M. c. vulpina* occurring in the Blue Mountains of northeastern Oregon (Hall 1981).

Compared to the Sierra subspecies, the Humboldt subspecies is darker, with a richer golden tone to the underfur, has a smaller and patchier gular patch that is more cream colored than orange and yellow (fig. 4), has a smaller skull, smaller and less crowded premolars, and a more narrow rostrum (Grinnell and Dixon 1926). Recent phylogenetic analyses continue to support the distinctiveness of the Humboldt subspecies, based on the presence of distinct haplotypes shared by historical museum specimens and martens in the extant range (Schwartz et al. 2016, Slauson et al. 2009b). Marten populations in coastal Oregon historically described as *M. c. caurina* also share these haplotypes, leading Slauson et al. (2009b) to suggest that martens on the Oregon Coast Range may be *M. c. humboldtensis*. More recent mitochondrial and nuclear DNA analyses throughout the Pacific States have strengthened the case that coastal California and coastal Oregon populations represent a single evolutionarily significant unit, and that coastal Oregon martens should be recognized as the Humboldt subspecies (Schwartz et al. 2016). Evolutionarily significant units are populations that are either geographically separated, show limited gene flow, or have locally adapted phenotypic traits caused by differences in selection.

Recent mitochondrial and nuclear DNA analyses throughout the Pacific States have strengthened the case that coastal California and coastal Oregon populations represent a single evolutionarily significant unit, and that coastal Oregon martens should be recognized as the Humboldt subspecies.



Figure 4—Comparison of overall pelage coloration and the extent of gular patches on typical historical museum specimens of the (A) Humboldt marten (*Martes caurina humboldtensis*) in California and (B) Sierra marten (*M. c. sierrae*). Specimens were photographed at the Museum of Vertebrate Zoology, University of California, Berkeley.

Historical Distribution: Coastal California and Coastal Oregon

To describe the historical distribution of martens, we used the locations of verifiable museum specimens, trapping records, or published interviews with trappers prior to the 1950s, as summarized by Zielinski et al. (2001). The historical distribution of the Humboldt marten in California included the northern Coast Range from the Oregon border southward to northwestern Sonoma County, “within the narrow northwest humid coast strip, chiefly within the redwood belt from near sea level to about 3000 ft” (Grinnell et al. 1937) (fig. 5). Of the 24 historical records of Humboldt marten occurrence, 20 (83 percent) occurred <25 km from the coast; no records occurred >35 km from the coast (Grinnell et al. 1937). Outside low-elevation coastal forests, early observations of the association of the Humboldt marten with dense shrub layers were made by trappers: “All trappers agree that, although martens have been taken along streams well down to sea level, martens are found mostly on the high ridges. This makes the trapping of them difficult, as the climb in winter is heart-breaking, owing to the wet tangle of brush and down timber, higher than one’s head...” (Grinnell et al. 1937). In the early 1900s, Grinnell et al. (1937) noted that the Humboldt marten was already rather uncommon, though in earlier years was fairly numerous. These authors reported a local account of individual trappers capturing 35 to 50 martens in one winter within a few miles of the coast.

The historical distribution of martens in coastal Oregon included the Coast Range from the Columbia River south through the coastal portions of the Klamath-Siskiyou Mountains to the California border (Zielinski et al. 2001) (fig. 5). Museum or trapping records for martens exist for every county within their historical range in coastal Oregon (Marshall 1994, Zielinski et al. 2001) (fig. 5). In Oregon’s coastal region, >90 percent of historical records of martens are from sites near the coast, with few records from the more inland portions of the region (Zielinski et al. 2001).

Contemporary Distribution and Abundance: Coastal California and Oregon

To describe the contemporary distribution of martens, we used the results of surveys conducted since the late 1980s that provided verifiable evidence of species occurrence, such as tracks, photographs, or DNA. Zielinski et al. (2001) and Slauson and Zielinski (2004) summarized pre-2005 survey efforts, and we summarized post-2005 surveys from published (Hamm et al. 2012, Moriarty et al. 2016, Slauson and Zielinski 2007, Slauson et al. 2009a) and unpublished sources (BLM,

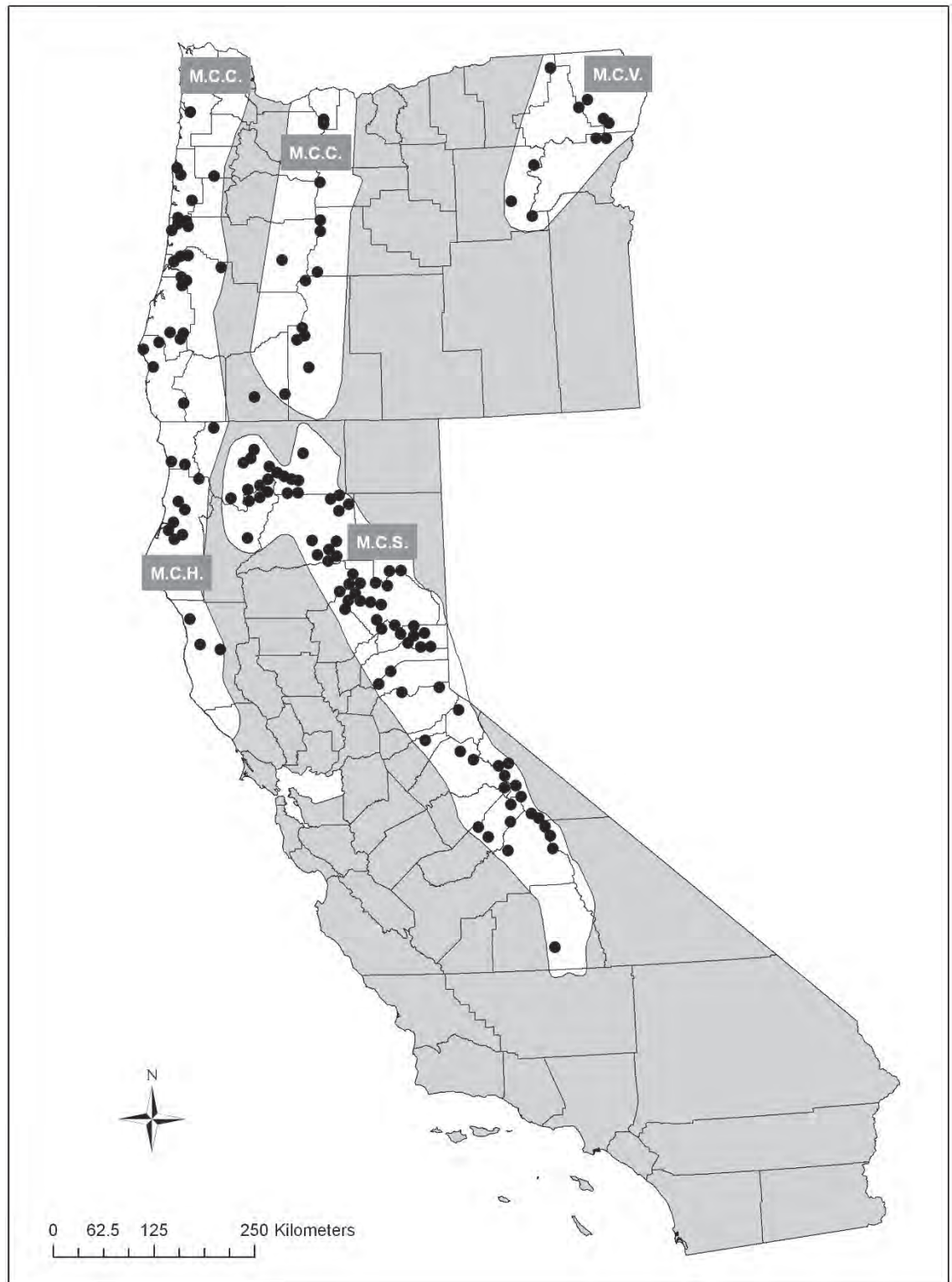


Figure 5—Historical range and distribution of historical records of occurrence for the four Pacific marten (*Martes caurina*) subspecies—*M. c. humboldtensis* (M.C.H.), *M. c. sierrae* (M.C.S.), *M. c. caurina* (M.C.C.), *M. c. vulpina* (M.C.V.)—in Oregon and California. Range boundaries and historical records modified from Zielinski et al. (2001).

California State Parks, Green Diamond Resource Company, Hoopa Valley Tribe, Humboldt Redwood Company, Mendocino Redwood Company, Redwood National Park, Yurok Tribe, USFS Pacific Southwest Research Station, and USFS Six Rivers National Forest). In central and north coastal Oregon where survey efforts have been sparse, we also included the locations of alternative verifiable evidence, including carcasses of road-killed individuals and the recent locations where martens have been legally trapped.

Despite surveys occurring at >3,000 locations within the historical range in California, representing >50,000 survey days of effort, the Humboldt marten is known only from two disjunct remnant populations occupying <5 percent of its historical range in the state (fig. 6). In 2008, the larger of the two populations occupied a 100-percent minimum convex polygon area of 62 700 ha (Slauson et al. 2009a). Although this area may appear large, both martens and suitable marten habitat are patchily distributed throughout the area. The 2008 estimate of the total population size occupying that area was <100 individuals (Slauson et al. 2009a). Survey efforts since 2008 in the vicinity of this population have detected martens in a few new locations, primarily along the edges of the known occupied area, representing an increase of <5 percent in the overall occupied area.

From 2011 through 2015, multiple marten detections were reported in a new area near the California-Oregon border in northeast Del Norte County, California (fig. 6). Based on criteria regarding distance between survey stations, these are believed to represent 12 independent detections (Slauson 2016). Additional surveys will be necessary to determine if this population is isolated from or connected to the southern coastal Oregon population to the north or the main California population to the south.

In coastal Oregon, surveys for martens have begun in recent years, but the current distribution of marten populations is not yet well understood, and no population size estimates outside the dune forest habitat west of U.S. Highway 101 are available. Contemporary detections have occurred in two distinct areas: on or near the Siskiyou National Forest in the south (Curry County), and on or near the Siuslaw National Forest to the north (Lincoln, western Lane, western Douglas, northwestern Coos Counties) (Moriarty et al. 2016 Zielinski et al. 2001) (fig. 6). In addition, road-killed martens have been found on U.S. Highway 101 in the immediate vicinity of the Siuslaw National Forest and Oregon Dunes National Recreation Area (fig. 6). Based on modeled habitat suitability (see the “Contemporary Landscape Habitat Suitability” section), existing conditions in the central and northern Oregon Coast Range may only be sufficient to support a single population on or near the Siuslaw National Forest.

Despite surveys occurring at >3,000 locations California, the Humboldt marten is known only from two disjunct remnant populations occupying <5 percent of its historical range in the state.



Figure 6—(A) Distribution of contemporary survey effort and (B) contemporary verifiable Humboldt marten (*Martes caurina humboldtensis*) detections from surveys (circles), and roadkill mortalities ($n = 14$) or trapped ($n = 3$) individuals (asterisks) in the assessment area.

Life History

Territoriality

Martens exhibit intrasexual territoriality, with males excluding males and females excluding females from their home ranges (Powell 1994). Adult females will occasionally allow female offspring to establish home ranges in portions of the adult's home range. This strategy might improve female offspring survival during the early dispersal period and ensure that high-quality reproductive habitat is passed on through matriline. Male and female home ranges typically overlap, with dominant males maintaining home ranges that encompass one or more female's home range (Powell 1994). Although paternity studies for martens are lacking, we assume that males with home ranges encompassing reproductively active females usually sire the young compared to males occupying adjacent home ranges, as has been demonstrated in the fisher (Aubry et al. 2004). However, males occasionally make substantial movements from their home ranges during the breeding season to increase their opportunities for reproduction.

Activity Patterns

Martens are active year-round, adjusting their activity patterns seasonally to synchronize with those of key prey species (Zielinski et al. 1983). Accordingly, martens may be active at any time of day. Peak diurnal activity typically occurs during summer when ground-dwelling sciurids and young birds are key prey. Peak nocturnal activity is typically during winter when nocturnal prey species, such as Humboldt flying squirrels (*Glaucomys oregonensis*) or snowshoe hares (*Lepus americanus*), become more important (Zielinski et al. 1983, 2008).

Food Habits and Habitat-Prey Relationships

Martens are considered dietary generalists; however, their diet changes with seasonal prey availability, and during particular seasons they may specialize on a few prey species (Martin 1994, Zielinski et al. 1983). Overall, mammals dominate the diet, but birds, insects, and fruits are important seasonally (Martin 1994, Zielinski et al. 1983). In the Sierra Nevada and Cascade Mountains of California, the winter prey of Sierra martens is primarily Douglas's squirrels (*Tamiasciurus douglasii*), snowshoe hares, western red-backed voles (*Myodes californicus*) and other voles (*Microtus* sp.), and northern flying squirrels (*Glaucomys sabrinus*) (Slauson and Zielinski 2010, Zielinski et al. 1983). In summer, the diet changes to focus on ground-dwelling sciurids, although voles continue to be important prey (Martin 1994, Zielinski et al. 1983).

Prey body size appears to be an important factor in prey selection by the Humboldt marten, with medium-size prey (85–225 g) representing 55 to 66 percent of summer through winter diet, and used 2.6 times more than small (<40 g) and 8.4 times more than large (>250 g) prey, respectively.

Slauson and Zielinski (2017) analyzed the diet of Humboldt martens from the main California population. (Unless otherwise cited, the following information on Humboldt marten diet is based on findings of that study.) They calculated the importance of the prey species in the diet from 528 scats collected in all seasons (winter: $n = 53$, 10 percent; spring: $n = 41$, 8 percent; summer: $n = 151$, 29 percent, and fall: $n = 277$, 52 percent) using the proportion of metabolizable energy (PME). Mammals dominated the overall diet (PME = 72 percent), followed by birds (PME = 18 percent), with berries, insects, and reptiles collectively contributing <10 percent PME. This analysis indicated that mammals and birds were eaten year-round, while reptiles, insects, and berries were eaten only seasonally (fig. 7). While >37 prey species were identified in the overall diet, only 11 species contributed >5 percent PME, and the majority (59 to 64 percent) of PME during any one season was composed of only four taxa (chipmunks [*Tamias* sp.], medium-size birds [40 to 200 g], western red-backed voles, and either Douglas's squirrel [summer-fall], Humboldt flying squirrel [winter], or large birds [>200 g; spring]). Overall, sciurids were the most important prey group, comprising 42 percent of PME of the annual diet and varying seasonally: 50 to 51 percent during summer-fall; 29 to 34 percent during winter-spring. Chipmunks were the most important single prey species from summer through fall, contributing 23 to 34 percent PME during those seasons (fig. 7). Prey body size appears to be an important factor in prey selection by the Humboldt marten, with medium-size prey (85–225 g) representing 55 to 66 percent of PME from summer through winter, 2.6 to 8.4 times the PME compared to small (<40 g) or large (>250 g) prey, respectively. During winter, when important medium-size prey (e.g., chipmunks) were consumed least often (likely because of their reduced availability), Humboldt martens shifted to alternative medium-sized prey (birds and Humboldt flying squirrels) and large prey (fig. 7).

Identification of bird species in scats is difficult and many samples are not taxonomically identifiable beyond class, but body size categories can be assigned based on the relative sizes of structures such as flight feather shafts, claws, and bills. The majority of identifiable birds taken by martens were passerines, including year-round residents (e.g., Steller's jay, *Cyanocitta stelleri*), and summer- (e.g., Parulidae [New World warblers]) and winter-migrant (e.g., varied thrush, *Ixoreus naevius*) species. Woodpecker remains (e.g., northern flicker, *Colaptes auratus*) also appeared in the sampled scats.

The frequency of berries in Humboldt marten scats was higher than that reported by Martin (1994) for other North American martens. Of the berries identified, over 90 percent were ericaceous species including salal (47 percent), evergreen huckleberry (31 percent), red huckleberry (21 percent), and manzanita

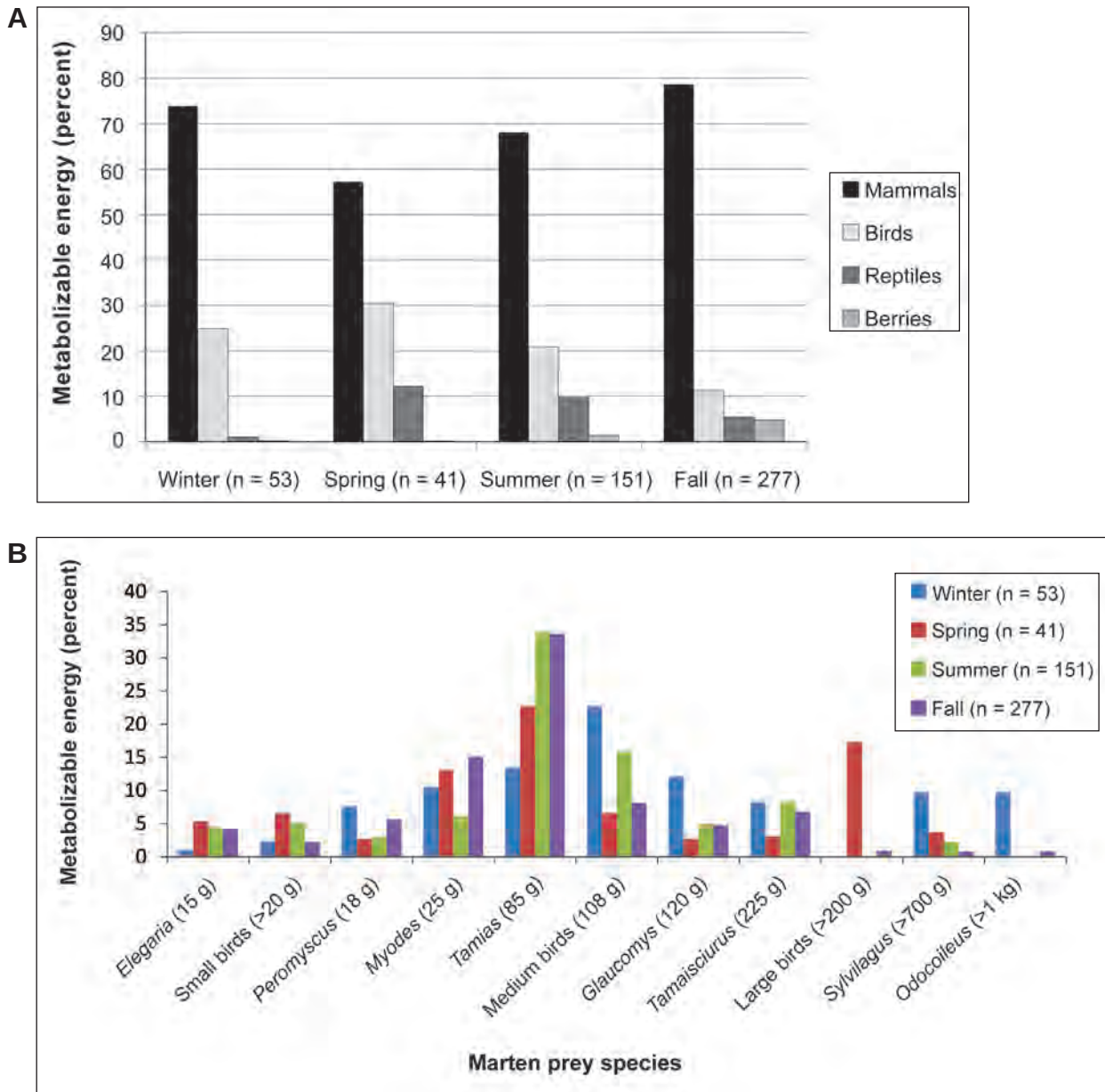


Figure 7—Summer and fall diet composition of the Humboldt marten (*Martes caurina humboldtensis*) in California by: (A) percentage of metabolizable energy for major prey groups, and (B) percentage of metabolizable energy contributed by each prey species by season. Only mammal species representing ≥ 5 percent of metabolizable energy consumed are presented. These results are based on 528 scats collected in Humboldt and Del Norte Counties, California, from 2000 to 2014 (Slauson and Zielinski, 2017).

(*Arctostaphylos* sp.) (13 percent). Although insect remains frequently occurred in scats, the only scats composed entirely of insects had native wasps (*Vespula* sp.), bald-faced hornets (*Dolichovespula maculata*), and nonnative European honey bees (*Apis mellifera*). These species comprised 53 percent of all insect prey taken, with use peaking in the summer and early fall when raiding hives would yield the maximum energy content of larvae from native species, and larvae and honey from nonnative honey bees.

In contrast to much of the marten's range in North America, in most of the assessment area winter snowfall is rare and no persistent snowpack forms. This has important implications for seasonal prey availability. In regions where snowpack forms, prey species such as chipmunks, voles, and semifossorial insectivores become less available to martens, but owing to the lack of significant snowpack in the assessment area, these species may be more available during late fall, winter, and early spring. Furthermore, the snowshoe hare, an important winter prey species throughout much of the marten's range, is found only in the northern Oregon Coast Range portion of the historical range of the Humboldt marten (Verts and Carraway 1998). As a result of these factors, winter diet of the Humboldt marten exploits a broader range of taxa than other North American marten subspecies.

Many of the Humboldt marten's key prey species (e.g., western red-backed vole [Hayes and Cross 1987, Rosenberg et al. 1994, Zabel and Waters 1992], flying squirrel [Waters and Zabel 1995], Douglas's squirrel [Carey 1991, Carey and Johnson 1995]) reach their highest densities in forest stands with mature and late-successional structural features where their key food resources—conifer seed crops and truffles (fruiting bodies of ectomycorrhizal fungi)—are most abundant (Luoma et al. 2003, Smith et al. 2002). Also, the density of ericaceous shrub layers is positively correlated with chipmunk density (Hayes et al. 1995), Humboldt flying squirrel abundance (Carey 1995), and overall small mammal abundance (Carey and Johnson 1995) in coastal Oregon. Coarse woody debris is also positively associated with overall small mammal abundance (Carey and Johnson 1995), and density of large snags is a predictor of abundance of Humboldt flying squirrels (Carey 1995) in coastal Oregon. Andruskiw et al. (2008) found American martens' hunting success to be lower after logging reduced the physical complexity provided by coarse woody debris on or near the forest floor. Many bird species preyed upon by martens are associated with shrub understories (e.g., Hagar 2003) and use fruits of ericaceous species as residents and migrants (e.g., Tietz and Johnson 2007).

Many of the Humboldt marten's key prey species (red-backed voles, flying squirrels, Douglas's squirrels) reach their highest densities in forest stands with mature and late-successional structural features where their key food resources—conifer seed crops and truffles—are most abundant.

Reproduction

Martens are polygamous with females solely responsible for raising young. Mating is largely known from the behavior of captive animals, where mating occurs from late June to early August, with a peak in July (Markley and Bassett 1942) (fig. 8). Females typically give birth in March and April (Strickland et al. 1982) and female Humboldt martens have a mean parturition date of April 13 (Delheimer et al. n.d.). Females do not mate until 15 months of age, and owing to delayed implantation, will not produce their first litters until at least 2 years of age (Strickland et al. 1982). In an Ontario study, Thompson and Colgan (1987) reported that <25 percent of yearlings produced ova, and in Quebec, Fortin and Cantin (2004) reported a range of 40 to 76 percent with ova among 83 yearling martens over a decadal period. Not all females ≥ 2 years old give birth in a given year; Thompson and Colgan (1987) reported pregnancy rates of 50 percent of females during years of environmental stress. However, in the Sierra Nevada of California during 2009–2011, all 20 captured females ≥ 2 years old were lactating, indicating that they were all actively attempting to raise young (Slauson 2017). This study included both mild and severe winters, including 2011, 1 of the top 10 snowfall years in the Sierra Nevada in the last century (Slauson 2017). This suggests that in California, regardless of the effects of winter conditions on prey populations, adult female Pacific martens may be more likely to attempt to produce litters annually than martens in more northern portions of North America where prey populations such as snowshoe hares fluctuate more severely. However, annual variation in environmental conditions and prey populations will still affect survival rates of various age classes.

Females are capable of producing from one to five kits per litter, but the reported averages are between two and three (Mead 1994, Strickland and Douglas 1987). Female Humboldt martens have a mean litter size of 1.8 (SE = 0.15; Delheimer et al. n.d.). Further evidence suggests age-related fecundity in martens, with the highest number of kits produced by 3- to 5-year-olds and the lowest number by first-year breeders and females >5 years old (Fortin and Cantin 2004, Mead 1994). No data exist on the average number of young martens raised to weaning or recruited into the population per breeding female. An understanding of recruitment and the effects of annual variation in environmental conditions and prey populations on kit survival are important information gaps.

Survivorship and Longevity

Longevity in martens is not well understood because (1) most studies of longevity are from trapped populations where the age structure was truncated and captures biased toward younger individuals, and (2) few studies of untrapped populations

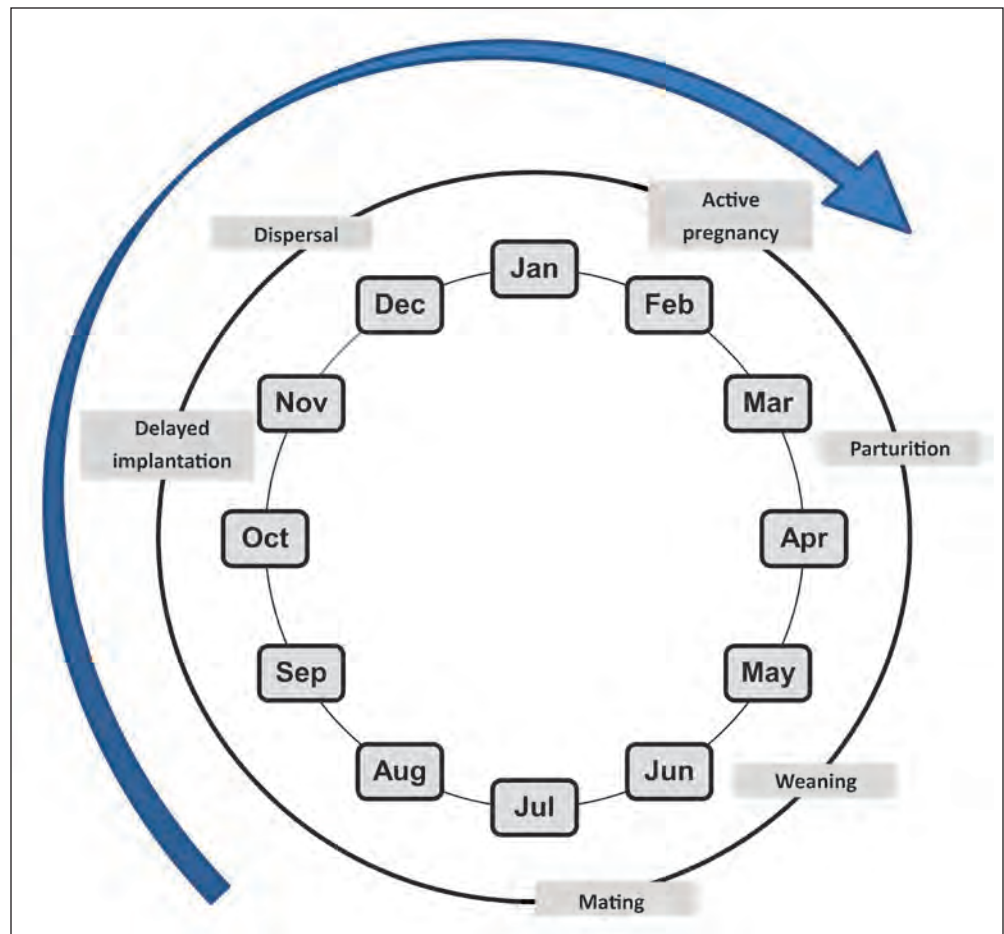
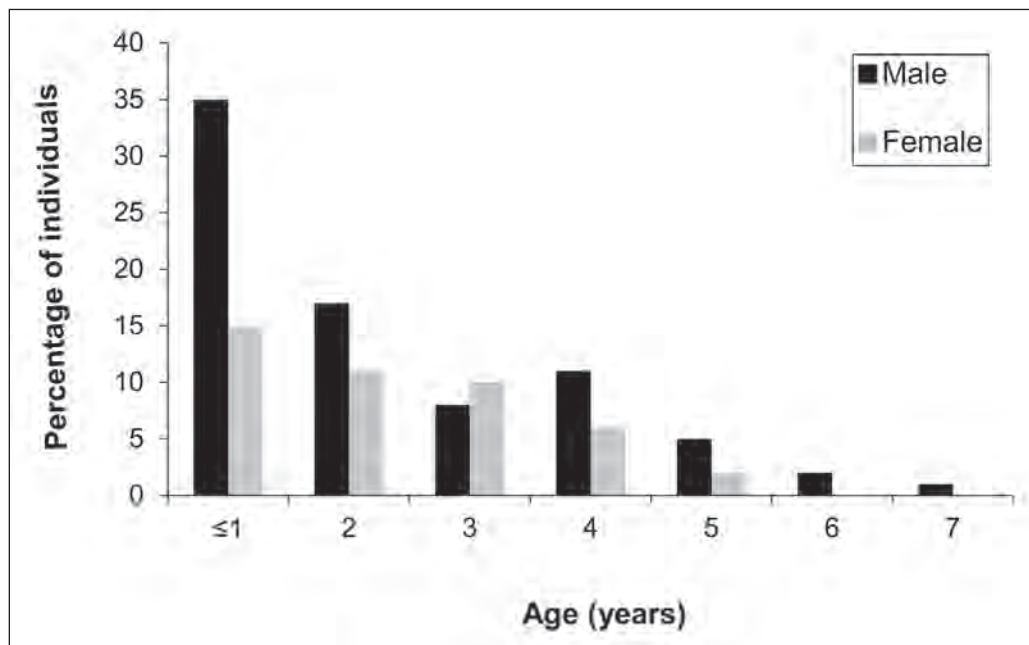


Figure 8—Annual reproductive cycle for North American martens (*Martes caurina*, *M. americana*).

have reported age structure. Captive martens have been reported to reach 15 years of age, but there is no evidence to suggest many individuals in wild populations approach this age. In two marten populations subject to trapping in Ontario and Quebec, only about 10 percent of all trapped individuals (including approximately 1,000 females) were >5 years old (Fortin and Cantin 2004, Strickland and Douglas 1987). All 22 martens captured from an untrapped population in northeastern Oregon were <5 years old (Bull and Heater 2001). Over a 3-year period, age structure among 96 martens from an untrapped population in the Sierra Nevada Mountains of California had relatively consistent proportions of yearling and adult age classes, with only 1 of 27 females (4 percent) observed >4 years of age (Moriarty et al. 2014, Slauson 2017) (fig. 9).

Factors influencing survival of untrapped populations of martens are poorly understood. Martens coexist in forested ecosystems with larger bodied mammalian and avian predators that occasionally prey on them. Therefore, predator avoidance

A. Lake Tahoe region marten population



B. Lassen region marten population

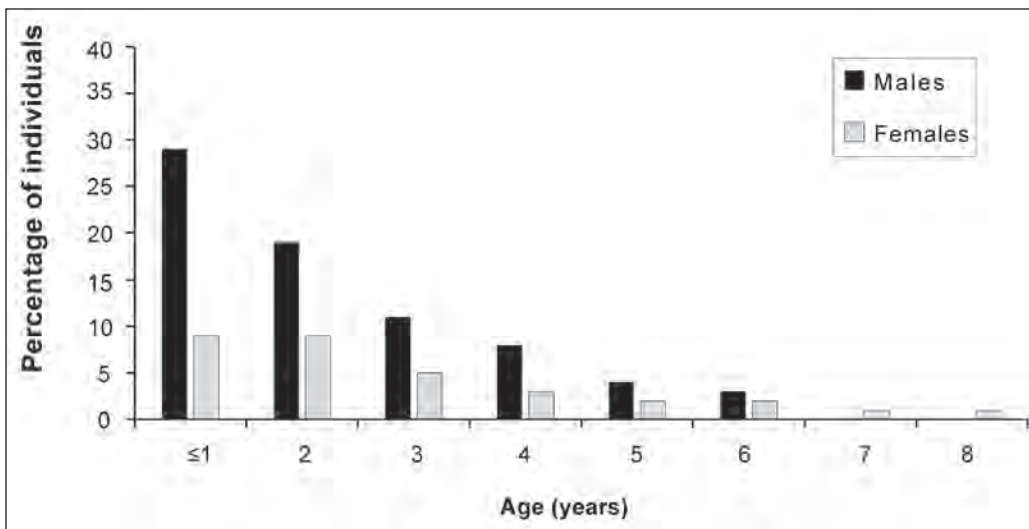


Figure 9—Age structure for untrapped populations of Pacific martens (*Martes caurina*) in the (A) Lake Tahoe region (n = 96) (Slauson 2017), and (B) Lassen region (n = 54) (Moriarty et al. 2014) of California from 2009 through 2012.

Collectively, the results of these studies indicate that widespread human-induced changes to forest structure are associated with increased predation risk for martens.

has likely been an important factor shaping their evolution, leading martens to select for highly complex forest structure and avoid areas lacking overhead and escape cover. By specializing on structurally complex boreal-montane forests, martens minimize their distributional overlap with larger bodied generalist predators such as bobcats (*Lynx rufus*) that typically use more diverse habitats, including younger forest stages and more open habitats such as oak woodlands and meadows.

Among reported mortality sources, the proportion of predation events varies by landscape condition. Predation represented 62 percent (Bull and Heater 2001) and 75 percent (McCann et al. 2010, Wilk and Raphael 2018) of mortality events in moderately to heavily logged forest compared to 40 percent in a forest reserve (Hodgman et al. 1997). The species of predators that killed martens in these studies also varied between moderately to heavily logged forests and forest reserves, with generalist carnivores, including bobcats and coyotes (*Canis latrans*), responsible for 71 percent (Bull and Heater 2001) and 75 percent (Wilk and Raphael 2018) of predation events in intensively logged forests in Oregon versus 40 percent in a forest reserve in Maine (Hodgman et al. 1997).

Kill site characteristics are rarely reported in the literature, but in two studies the sites where martens were killed were associated with reduced escape cover in heavily logged stands (Wilk and Raphael 2018) or open shelterwood stands (Ellis 1998). In an ongoing study of Humboldt martens in intensively managed forests on the edge of the main California population, preliminary results have been consistent with these patterns. Predation was implicated in all cases where cause of mortality could be determined, the dominant predator was a generalist—the bobcat—(Slauson et al. 2014), and the majority of kill sites occurred in logged sites near roads (Slauson 2015). Preliminary results of a study on bobcat diet and habitat use in the same area show that bobcats prey primarily on herbivorous species such as dusky-footed woodrats (*Neotoma fuscipes*) and brush rabbits (*Sylvilagus bachmani*), and that bobcats select for regenerating harvested stands ≤ 30 years old (Slauson 2018) where these prey species are most abundant (e.g., Hamm and Diller 2009). Collectively, the results of these studies indicate that widespread human-induced changes to forest structure are associated with increased predation risk for martens.

Parasites and Disease

Little information is available on disease or parasite prevalence in the Pacific marten. Zielinski (1984) discovered antibodies to bubonic plague (*Yersinia pestis*) in 4 of 13 martens in the Sierra Nevada. He also found a chipmunk flea (*Monopsyllus ciliatus*) to be the most common ectoparasite, which was also probably the source of the plague transmission. Ticks are commonly encountered on trapped martens,

especially on the nape and in the ears during the spring and summer (K. Slauson, pers. obs.) and may be potential vectors of disease transmission to martens (Gabriel et al. 2012a). Sympatric populations of gray foxes (*Urocyon cinereoargenteus*) and fishers in or near the assessment area are known to have been exposed to viral and parasitic diseases such as canine distemper, parvovirus, toxoplasmosis, West Nile virus, and rabies, which are also known to be transmittable to martens (Brown et al. 2008, Gabriel et al. 2012a). Mustelids are among the species most susceptible to canine distemper disease (Deem et al. 2000); in black-footed ferrets (*Mustela nigripes*) distemper infection causes a fatality rate close to 100 percent (Bernard et al. 1984). Given the small population sizes of Humboldt martens in California (and probably in Oregon), lethal disease outbreaks have the potential for significant population-level effects.

Dispersal and Recruitment

Natal dispersal by young-of-the-year is generally thought to occur as early as August, with fall, winter, and spring dispersal periods also reported (Clark and Campbell 1976, Slough 1989) (fig. 8). Natal dispersal in the Humboldt marten occurs as early as August and continues at least until the following summer season (Slauson 2017). Dispersal has been divided into three phases with respect to the decisions faced by juveniles or adults and potential factors influencing those decisions: (1) whether to disperse from the natal area or home range, (2) search behavior, and (3) factors important to settlement (Bowler and Benton 2005, Stamps 2001). Incorporating the social or habitat factors in these phases of the dispersal process is critical to understanding how they may influence the outcome of dispersal events.

Although some adult male and female martens leave their home ranges during periods of low prey densities (Thompson and Colgan 1987), few studies have reported such behavior. Search behavior and travel distances of juveniles and adults are critical factors in understanding the effects of landscape patterns on dispersal. Although dispersal distances of >70 km have been reported for martens (e.g., Fecske and Jenks 2002), other studies have found that most juvenile American martens in both logged and unlogged landscapes dispersed much shorter distances (≤ 5 km [Broquet et al. 2006]; <15 km [Phillips 1994]; $\bar{x}$ 15.5 km, SE = 1.01 [Pauli et al. 2012]). Johnson et al. (2009) compared dispersing juvenile American martens in an unharvested forest landscape with others in a regenerating forest landscape that had been >80 percent logged 20 to 60 years earlier using a combination of selection and clearcut methods. In the regenerating landscape, juvenile martens traveled slower, moved shorter distances, had poorer body condition, and suffered twice the mortality rate (49 percent vs. 25 percent). These authors noted the findings of Andruskiw

Landscape pattern can have important effects on dispersal dynamics, affecting both the distance dispersers can traverse and their success rate in establishing home ranges and surviving to adulthood.

et al. (2008), who found that martens were more successful in obtaining prey in the unlogged versus the logged landscape. Although commercial trapping mortality occurred during this study, it was similar in both study landscapes, eliminating this concern in the interpretation of their results (Johnson et al. 2009). Landscape pattern can have important effects on dispersal dynamics, affecting both the distance dispersers can traverse and their success rate in establishing home ranges and surviving to adulthood.

The annual recruitment rate of juvenile cohorts in untrapped marten populations depends on three factors: (1) the number of young per female that reach the dispersal stage, (2) the success rate of dispersing juveniles in establishing home ranges, and (3) the effects of annual environmental stochasticity. In an untrapped Pacific marten population in the Sierra Nevada Mountains of California, annual juvenile recruitment represented approximately 40 percent of the total observed population size by the following breeding season and was relatively constant during a 3-year study period (Slauson 2017) (fig. 10).

Population Biology and Dynamics

Understanding the relative importance of population processes and life stages, such as yearling, subadult, and adult, to population growth is key to identifying management and conservation actions likely to benefit species’ persistence (Mills 2007). In

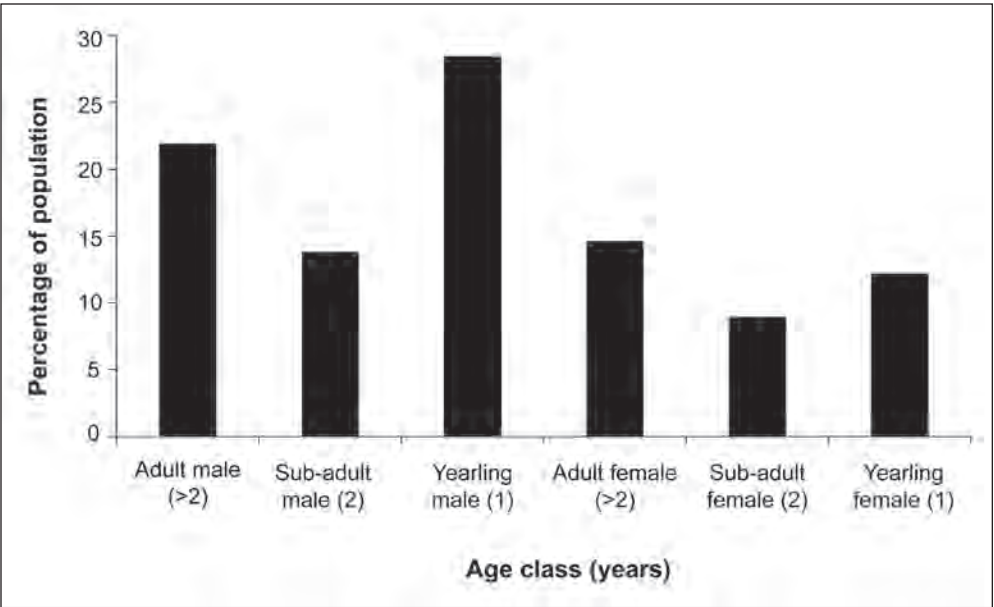


Figure 10—Percentages of yearling, subadult, and adult age classes by sex occurring annually in an untrapped population of Pacific martens in the Lake Tahoe region of California from 2009 through 2011. Population sampling occurred during May to July of each year (Slauson 2017).

this section, we review an existing stage-structured population model for martens developed by Buskirk et al. (2012) and evaluate its applicability to the Humboldt marten. Then we develop a revised version of this model using parameter estimates that are more realistic for the Humboldt marten. We then use these models to conduct sensitivity analyses to identify the relative effects that age-related survival and fecundity have on marten population growth.

For their model, Buskirk et al. (2012) estimated fecundity and survival rates by life stage based on review of marten studies across North America. Most of those studies were from marten populations accessible to trappers. Four stages were chosen, representing juveniles (stage 1: 0 to 1 year old), yearlings (stage 2: 1 to 2 years old), young adults (stage 3: 2 to 3 years old), and older adults (stage 4: >3 years old).

Buskirk et al. (2012) estimated the stable age distribution as 53 percent juveniles, 13 percent yearlings, 9 percent 2-year-olds, and 24 percent older animals. Elasticities, a measure of the proportional change in population growth rate over discrete time steps (λ) given an infinitesimal one-at-a-time proportional change in a demographic parameter (Mills 2007), showed that key transition rates were adult (stage 4) and juvenile (stage 1) survival. Adult and juvenile survival collectively accounted for a total of 52 percent of total elasticity. In contrast, fecundity accounted for only 21 percent of total elasticity across all stages (Buskirk et al. 2012). These results indicated that changes in adult and juvenile survival have a much larger relative impact on population growth rate than fecundity at any stage.

Buskirk et al.'s (2012) population modeling provided a first step in evaluating the importance of life stages on marten population growth. However, several of their model parameters may not be representative for the Humboldt marten owing to their reliance on data from northern marten populations and from populations subject to trapping.

First, fecundity estimates for 1-year-old martens used by Buskirk et al. (2012) were higher than those from untrapped California populations in the Sierra Nevada. Of 14 yearling Sierra marten females, only 3 (21 percent) showed evidence of lactation during 2009–2011 (Slauson 2017). Moreover, female American martens breeding for the first time have shown lower overall success rates in raising kits to dispersal age (Kartashov 1989, Thompson and Colgan 1987). Therefore, we reparameterized yearling fecundity using a lower pregnancy rate of 0.18, resulting in a yearling fecundity rate of 0.16.

Second, considering multiple sources, Buskirk et al. (2012) chose a juvenile survival rate of 25 percent. However, Potvin and Breton (1997) estimated juvenile survival at 61 percent, and Johnson et al. (2009) found that 49 percent of juveniles

dispersing in unlogged forest survived to establish home ranges and become adults, even where trapping occurred. Therefore, we chose the rate of 0.50 for juvenile survival to better represent the expected juvenile survival rate in untrapped populations in more intact forests.

Third, both trapped and untrapped populations rarely contain individuals >5 years of age. If all stages >1 year old have survival rates of 0.75 as suggested by Buskirk et al. (2012), the final stage would have more individuals than would be expected based on field data of population age structures (Bull and Heater 2001, Fortin and Cantin 2004, Slauson 2017). Therefore, we chose a lower survival rate of 0.70 for all stages >1 year old. We believe these three changes create a more realistic model for untrapped or lightly trapped marten populations and, specifically, for Humboldt marten populations (fig. 11).

The stable age distribution from our model includes 42 percent juveniles, 20 percent yearlings, 13 percent 2-year-olds, and 25 percent ≥ 3 -year-olds (fig. 11). Similar to Buskirk et al.'s (2012) results, elasticities revealed that key transition rates were for adult (≥ 3 -year-olds), juvenile, and yearling survival (25 percent, 21 percent, and 19 percent of total elasticity, respectively). Reproduction had the greatest elasticity for adults (≥ 3 -year-olds) (13 percent of total elasticity), but was low overall, accounting for a total of 20 percent elasticity across all stages.

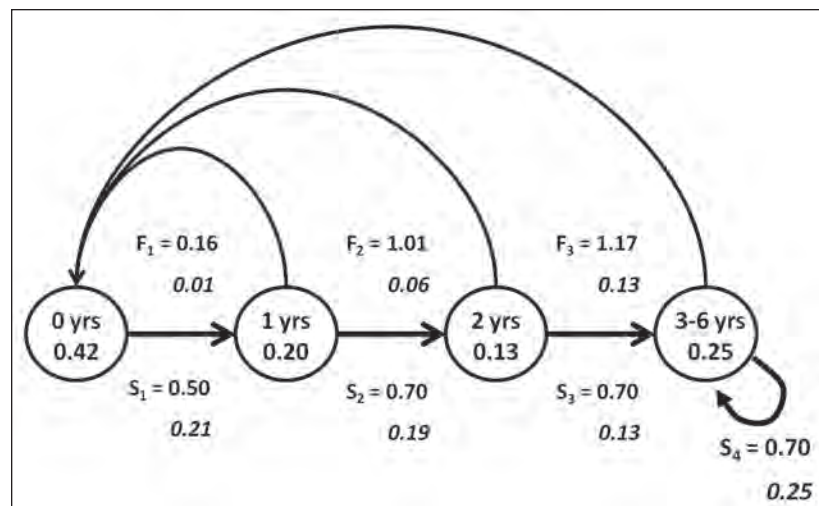


Figure 11—Life cycle diagram for untrapped Pacific marten (*Martes caurina*) populations (including the Humboldt marten) modified from Buskirk et al. (2012) by substituting parameter estimates that better characterize untrapped populations. Stable age distribution is indicated in each circle, below the age class. Elasticities are indicated in italics below each survival probability (S) or fecundity (F) estimate.

The results of both Buskirk et al.'s (2012) and our matrix models suggest that variation in survival across all stages, and especially among adults, has a much larger impact on population growth than variation in fecundity. Rates of pregnancy and kit production appear fairly constant in field data for untrapped populations in California, further suggesting that survival is the most important variable in marten population persistence and growth.

Thus, factors influencing marten survival have important management and conservation implications. Rather than expecting that marten populations will be capable of growing quickly in temporarily favorable environments, managers should anticipate that stable conditions and long time periods will be required for population growth and recovery (Buskirk et al. 2012). Analytical elasticities can be valuable for evaluating the relative importance of variation in vital rates on population growth, but it also is important to consider how each vital rate actually varies in unmanaged and managed environments (Mills 2007). Because a large portion of the assessment area is under commercial timber management, and there are strong indications of higher predation and lower survival rates in harvested forests, the relationship between various silvicultural practices and vital rates is an important area for future research. Johnson et al. (2009) made an important link between juvenile survival and the landscape condition resulting from intensive timber harvest, demonstrating a 50 percent reduction in juvenile survival in a landscape dominated by young clearcut and selectively harvested forest versus a landscape dominated by older uncut forest. This magnitude of effect has important implications for reduced population growth. How survival in untrapped populations is influenced by less intensive silvicultural practices, as well as how and why other vital rates vary, are also important areas for future research.

Rather than expecting that marten populations will be capable of growing quickly in temporarily favorable environments, managers should anticipate that stable conditions and long time periods will be required for population growth and recovery.

Intraguild Predation and Interspecific Competition

Martens are susceptible to predation by larger mammalian and avian predators, typically habitat-generalist species, including coyote, bobcat, and great horned owl (*Bubo virginianus*) (Bull and Heater 2001, Thompson 1994). In addition, fishers are known to kill martens (e.g., McCann et al. 2010), and dense fisher populations can limit the distribution of marten populations (Krohn et al. 1997, 2004). Intraguild killing in carnivores follows predictable body size relationships, with species pairs with 2.5 to 4 times the body mass most likely to participate in killing, with the larger species always the winner (Donadio and Buskirk 2006). We adapted the predictions using these body mass relationships for the community of mesocarnivores most often co-occurring with martens in the Pacific States (fig. 12). As discussed above, marten populations in logged forest landscapes have lower survival rates

Because survival is the most influential parameter in population performance, predation rates can have meaningful effects on marten abundance and population growth rates.

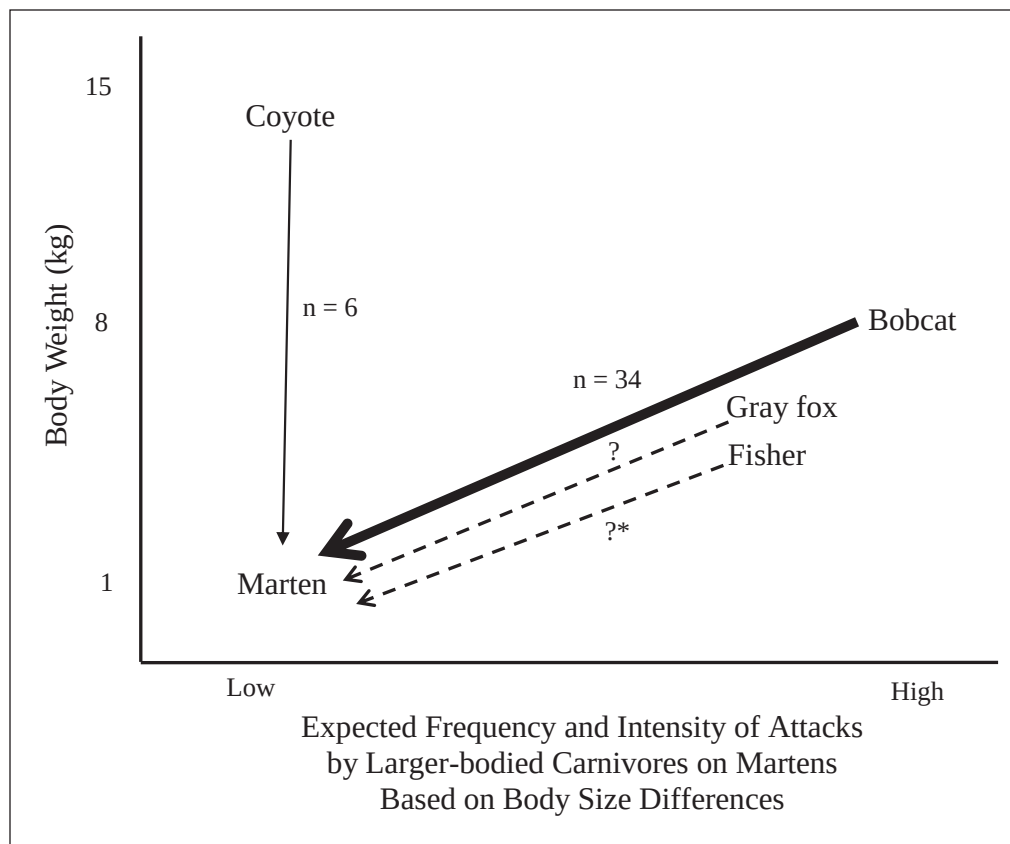


Figure 12—Intraguild predation relationships between larger-bodied carnivores and Pacific martens (*Martes caurina*). Solid arrows connect carnivores confirmed to kill Pacific martens from field studies. Relative weight of arrows indicates the number of documented cases of intraguild predation on Pacific martens (Bull and Heater 2001, Raphael 2004, Slauson et al. 2014). The single dashed arrow indicates a likely predator based on body mass ratio (Donadio and Buskirk 2006), but yet to be confirmed by field studies. The asterisk denotes a carnivore that has been confirmed to kill American martens (*M. americana*) (Hodgeman et al. 2000, McCann 2010) but has yet to be observed for the Pacific marten.

from natural causes such as predation than those in uncut landscapes, and the species most commonly reported as predators on martens tend to be habitat generalist carnivores and raptors (Bull and Heater 2001, Thompson 1994). In an ongoing study of dispersing Humboldt martens in an intensively managed landscape in California, 9 of 20 (45 percent) radio-collared martens monitored for >6 months were killed by bobcats (Slauson et al. 2014). Minimizing predation risk probably shapes martens' daily decisions as to where to forage and rest as well as broader decisions regarding dispersal and home range establishment. And, because survival is the most influential parameter in population performance, predation rates can have meaningful effects on marten abundance and population growth rates.

Multiscale Habitat Use

Pacific and American martens have been shown to select habitat at three primary spatial scales: microhabitat, stand, and home range (fig. 13). These three scales represent three of the four orders of habitat selection proposed by Johnson (1980), with the microhabitat scale representing 4th order, stand scale representing 3rd order, and home range scale representing 2nd order selection. The distribution of suitable habitat at the landscape scale (the 1st order per Johnson 1980) also has important influence on marten dispersal, home range scale habitat selection, and population density.

At the microscale, martens select specific structures for foraging or resting, such as large logs, which they run along searching for prey, or cavities in snags that provide thermal benefits (Taylor 1993) and reduce predation risk while denning or resting. At the stand scale, martens select forest stands with the structural features that provide one or more life history requirements (e.g., prey populations, foraging structures, and resting structures). At the home range scale, martens position their

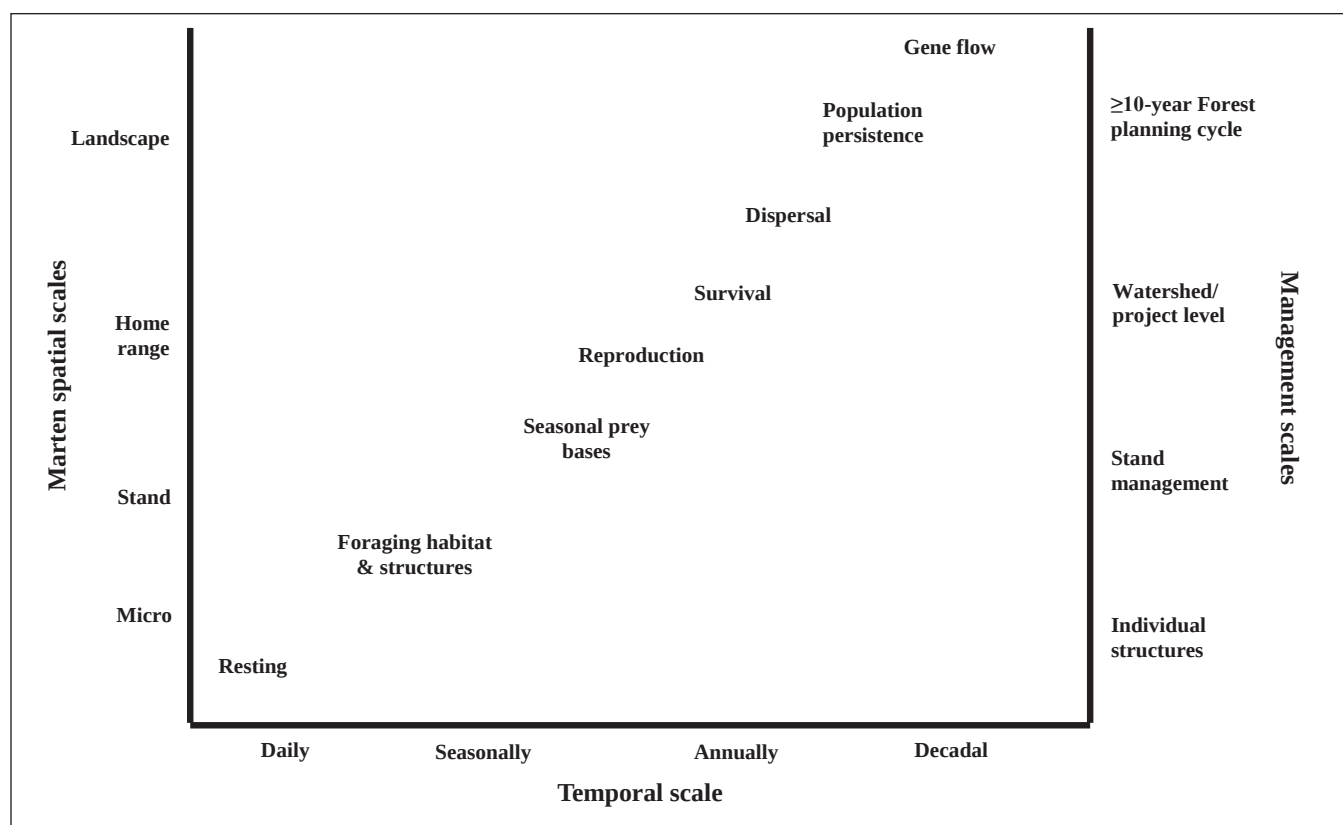


Figure 13—Conceptual relationships between Pacific marten (*Martes caurina*) life history needs and the spatial and temporal scales at which habitat meets those needs. The Z-axis indicates how management scales relate to marten habitat use and life history needs.

Habitat selection by martens appears to be strongest amongst all scales during the process of home range establishment, where individual martens select where to locate home ranges in order to include the resources to support their year-round life history needs and avoid same-sex conspecifics.

home ranges to include enough high-quality habitat to provide for life history needs (e.g., seasonal prey bases, den sites) and access to mates, while avoiding individuals of the same sex (Katnik et al. 1994). At the landscape scale, dispersing individuals select suitable portions of the landscape that are unoccupied by individuals of the same sex to establish home ranges (Johnson 2008). At the landscape scale between populations, marten dispersal maintains adjacent populations (or metapopulation structure where it exists) along with gene flow.

In a recent review of habitat selection by both North American marten species, Thompson et al. (2012) found that habitat selection appeared to be strongest amongst all scales during the process of home range establishment, where individual martens select where to locate home ranges in order to include the resources to support their year-round life history needs and avoid same-sex conspecifics. Furthermore, they reported that martens use managed landscapes “where sufficient cover and structures important to fitness are present and where the species can exhibit landscape-scale selection to maintain 70 percent or more of home ranges in suitable habitat conditions.”

At the landscape scale, marten population density declines as suitable habitat declines from either wildfire or timber harvest. Although martens generally select mature and old forests over young regenerating stands, habitat use varies across the continent, making generalization difficult at the stand scale. Variation in the selection for older forests appears to be linked to key aspects of marten ecology, including the abundance of key prey species, predator distribution, and the development of structural complexity near the ground in different forest types (Thompson et al. 2012). Consequently, assumptions about stand-scale habitat relationships should be ecosystem-specific and not based on general understandings from throughout their ranges.

Microscale Habitat Use: Resting and Denning Structures

Martens use rest structures daily between foraging bouts to provide thermoregulatory benefits and protection from predators (Taylor and Buskirk 1994). Short-term reuse rates for individual rest structures are typically low, and selection for structure type changes seasonally to meet thermoregulatory needs (e.g., Spencer 1987). Thus, many resting structures meeting various seasonal requirements are required across marten home ranges. Large-diameter live trees, snags, and logs provide the main types of resting structures for martens (Schumacher 1999, Slauson and Zielinski 2009, Spencer 1987). Slauson and Zielinski (2009) reported that among 55 rest structures used by Humboldt martens in the summer and fall, the most commonly used included snags (37 percent), downed logs (23 percent), and live trees (17 percent) (fig. 14). Less commonly used structures included large slash piles with



Rest structures used by Humboldt martens averaged 95 cm d.b.h. for snags, 88 cm max diameter for downed logs, and 94 cm d.b.h. for live trees; structures that on average exceeded 300 years of age.

large-diameter logs (10 percent), natural rock piles (8 percent), and shrub clumps (6 percent). Preliminary results of an ongoing study of Humboldt martens on more intensively managed lands also indicate that live trees, snags, and downed logs are the most commonly used rest structures (76 percent), with rock piles (11 percent) and slash piles (11 percent) used to a lesser degree (Slauson 2015). Although martens use human-created structures, such as slash piles, these structures appear to be most useful in summer when insulation from cold temperatures or damp conditions is not a requirement (Raphael and Jones 1997).

Martens typically select the largest available structures for resting and denning (Gilbert et al. 1997, Spencer 1987, Wilbert 1992). Rest structures used by Humboldt martens in largely unmanaged forest averaged 95 cm diameter at breast height (d.b.h.) for snags, 88 cm large-end diameter for downed logs, and 94 cm d.b.h. for live trees; structures that on average exceeded 300 years of age (Slauson and Zielinski 2009). Preliminary data on Humboldt marten rest structures from more intensively managed lands indicate a similar pattern of use of large-diameter conifer structures, with 70 percent of structures >70 cm d.b.h. (Slauson 2015). Most resting locations (i.e., the actual resting place in the structure) were in tree cavities (33 percent), on platforms in broken-top snags or on large live branches (33 percent), or in chambers within log piles or rock outcrops (28 percent) (Slauson and Zielinski 2009) (fig. 14). Rest structures provide cavities or chambers that likely become especially important during late fall through late spring, when wet and cold conditions are common.

Denning structures where females give birth to kits are called natal dens, and the locations where they later move their kits are referred to as maternal dens. Martens appear to be more selective of habitat conditions at den sites than at resting sites (Thompson et al. 2012). Characteristics of den structures and their surrounding stands each influence den-site selection (Ruggiero et al. 1998). High-quality foraging habitat near den sites is likely important, allowing females to maximize energy gained from foraging during lactation and minimize time spent away from their kits, especially when kits are dependent on their mothers for thermoregulation. The most common den structures used by North American martens are large-diameter live and dead trees with cavities (Thompson et al. 2012).

As of 2015, nine natal dens and 25 maternal dens had been described for the Humboldt marten. The majority (66 percent, $n = 6$) of natal dens were in cavities in large-diameter hardwoods (average d.b.h. = 101.8 cm), with a single snag (114 cm d.b.h.), single downed log, and single subterranean location used (Delheimer et al. n.d.). Maternal dens were primarily in cavities (85 percent) in 18 live trees (92.9 cm average d.b.h.), five snags (145 cm average d.b.h.), one rock pile, and one marten box (Delheimer et al. n.d., Slauson and Zielinski 2009).

Stand-Scale Habitat Use

Martens select forest stands that provide habitat structure supporting one or more life history needs that include foraging, resting, or denning. In addition, stand structure features that may reduce the risk of predation, such as dense overhead vegetation and vertical tree boles, could also be important. In general, the Pacific marten is associated with late-successional conifer stands (Powell et al. 2003) characterized by an abundance of large downed logs and large, decadent live trees and snags (Buskirk and Ruggiero 1994). Also, many key prey species occur in their highest densities in forest stands with late-successional structural features (e.g., western red-backed vole [Hayes and Cross 1987, Zabel and Waters 1992], northern flying squirrel [Waters and Zabel 1995], Douglas's squirrel [Carey 1991]), and dense ericaceous shrub layers (e.g., chipmunks [Hayes et al. 1995]). For reasons previously discussed, coarse woody debris is also an important component of stand structure, affecting both prey abundance and marten predation success (Andruskiw et al. 2008).

Analysis of Humboldt marten habitat selection in California revealed that they most strongly selected stands of old-growth, conifer-dominated forests with dense, ericaceous shrub layers (Slauson et al. 2007) (fig. 15). Late mature stands were used in proportion to availability, while stands in earlier successional stages were selected against (Slauson et al. 2007). The old-growth and late-mature stands selected by martens were most often dominated by Douglas-fir overstories, but also had mature hardwood understories composed of either tanoak or chinquapin. Shrub layers were dense (>70 percent cover), spatially extensive, and dominated by ericaceous species, including evergreen huckleberry, salal, and rhododendron (Slauson et al. 2007) (fig. 15). The majority of detections of martens in south coastal Oregon shared these same stand characteristics (Slauson and Zielinski 2001).

A recent study focusing on martens on more intensively managed lands on the western edge of the main California population found some martens using a mosaic of managed stands that were mostly harvested several decades ago. Many of those managed stands included substantial numbers of residual, large-diameter live and dead conifers and hardwoods. This work should provide new insight into compatible forest management alternatives where maintaining marten habitat and timber production are both management objectives (Slauson et al. 2014).

In addition to old-growth stands in highly productive soils, martens in coastal California and south coastal Oregon also have used forest- and shrub-dominated habitats occurring on less productive serpentine soils, hereafter called serpentine habitats. These habitats typically feature conifer-dominated overstories with dominant species, including lodgepole pine, western white pine, and Douglas-fir; but they also include dense (>70 percent cover) shrub layers dominated by huckleberry

Analysis of Humboldt marten habitat selection in California revealed that they most strongly selected stands of old-growth, conifer-dominated forests with dense, ericaceous shrub layers.

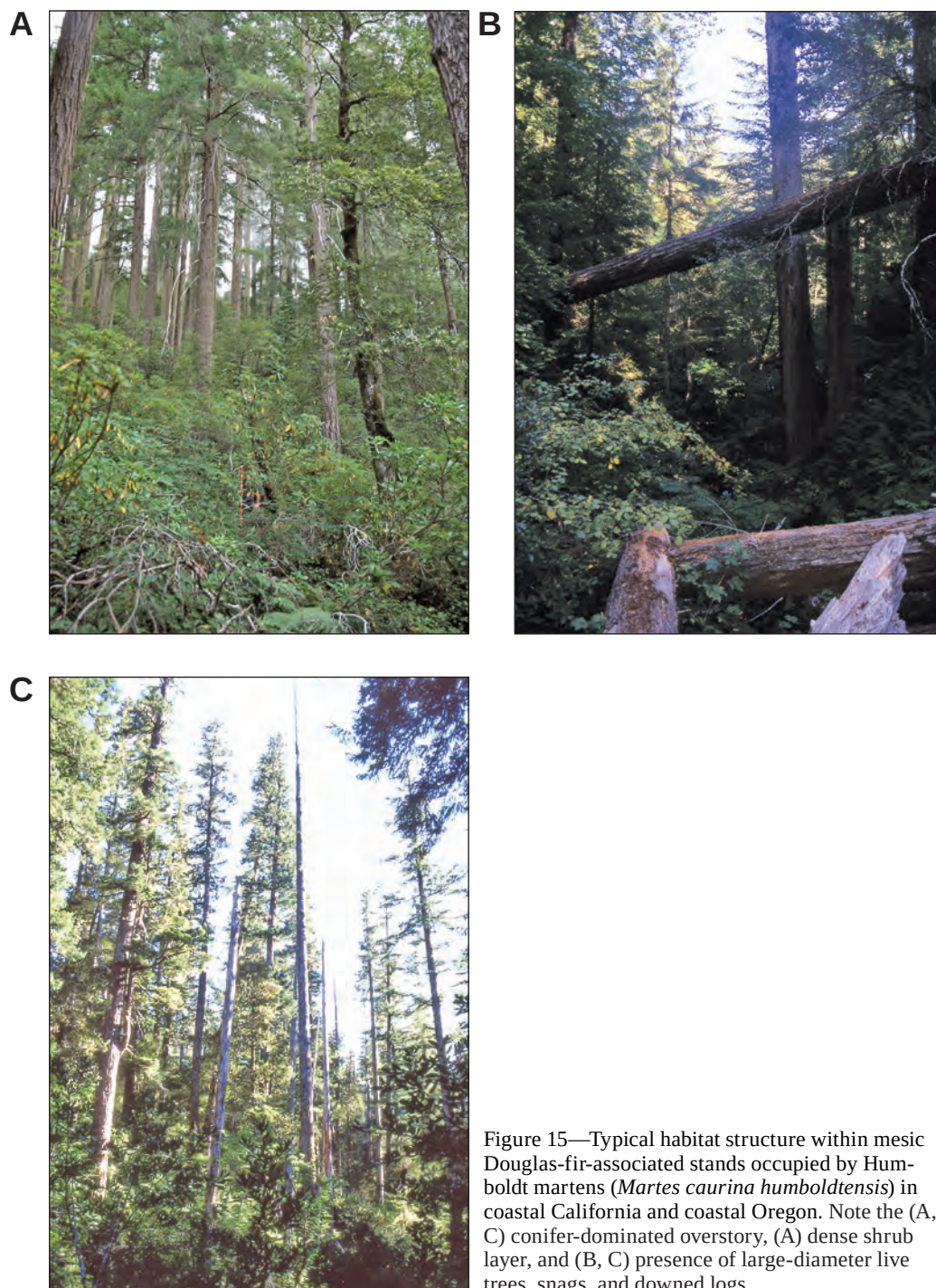


Figure 15—Typical habitat structure within mesic Douglas-fir-associated stands occupied by Humboldt martens (*Martes caurina humboldtensis*) in coastal California and coastal Oregon. Note the (A, C) conifer-dominated overstory, (A) dense shrub layer, and (B, C) presence of large-diameter live trees, snags, and downed logs.

oak, shrub form tanoak, and red huckleberry (Slauson and Zielinski 2001, Slauson et al. 2007) (fig. 16). In contrast to the dense old-growth stand structure martens use on productive soils, stands used in serpentine soils include any seral stage and with tree canopy closures ranging from sparse (20 percent) to dense (>70 percent; Slauson and Zielinski 2001, Slauson et al. 2007) (fig. 16). Serpentine habitats used by martens also contain abundant rocky outcrops, providing chambers that martens use as resting structures where large woody structures are rare (Slauson and Zielinski 2009). Although serpentine soils are extensively distributed in northwestern California and southwestern Oregon, martens have been found only in serpentine habitats in mesic, fog-influenced areas near (<30 km) the coast.

Martens in central coastal Oregon have been detected in surveys and found as roadkill (Moriarty et al. 2016, Zielinski et al. 2001) in and adjacent to shore pine and transitional shore pine-hemlock-Douglas-fir forests. Shore pine forests near these sites had many of the same characteristics as serpentine habitats, such as variable tree overstory with dense, spatially extensive ericaceous shrub understories (Chappell and Kagan 2001).

Martens in central coastal Oregon have been detected in shore pine and transitional shore pine-hemlock-Douglas-fir forests.

Home Range-Scale Habitat Use

Martens exhibit strong habitat selection at the home range scale, suggesting that this scale of selection directly influences an individual's fitness (Thompson et al. 2012). They establish home ranges to fulfill year-round resource needs as well as to access members of the opposite sex during the breeding season. Theoretically, a predator's home range size is a function of prey density and habitat quality; smaller home ranges typically represent better quality habitat conditions. Marten home ranges are often positioned to maximize the composition of high-quality habitat and minimize low-quality habitat (Phillips 1994) (fig. 17). Individual home ranges typically include a high proportion (≥ 70 percent) of suitable habitat (reviewed in Thompson et al. 2012). Females, as a result of their solitary role in raising young, have unique needs and must have access to reliable nearby prey resources to support the energetic demands of lactation and food provision for kits.

Amount and spatial distribution of high-quality habitat are related to marten home range size. As the amount of low-quality habitat (e.g., recent clearcuts or partial harvests) increases, home range size increases (Fuller and Harrison 2005, Potvin and Breton 1997, Potvin et al. 2000, Thompson 1994). Accordingly, the largest home range sizes for Pacific martens in California and Oregon, estimated at >1000 ha, are those of individuals occupying landscapes with extensive logging (Bull and Heater 2001, Ellis 1998, Self and Kerns 2001). The fitness consequence of larger home ranges with higher portions of managed stands (including regenerating clearcut,

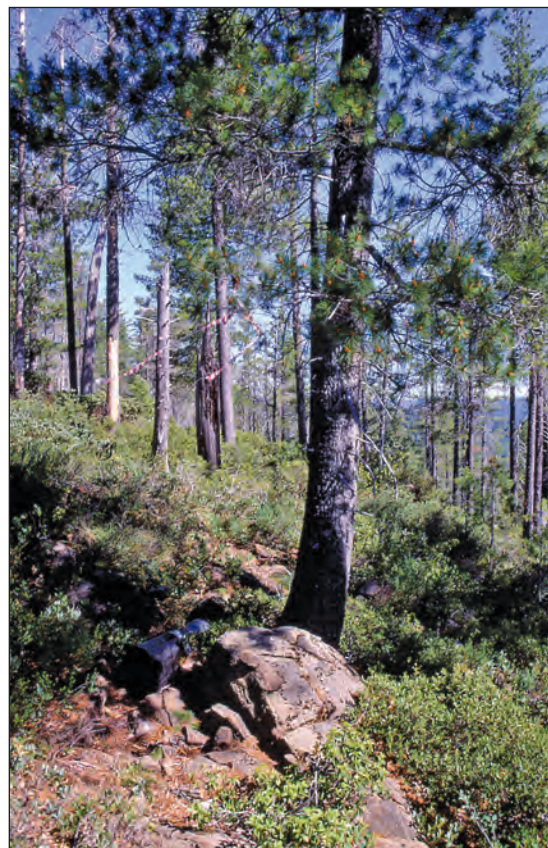


Figure 16—Typical habitat structure within mesic serpentine habitat occupied by Humboldt martens (*Martes caurina humboldtensis*) in California and south coastal Oregon.

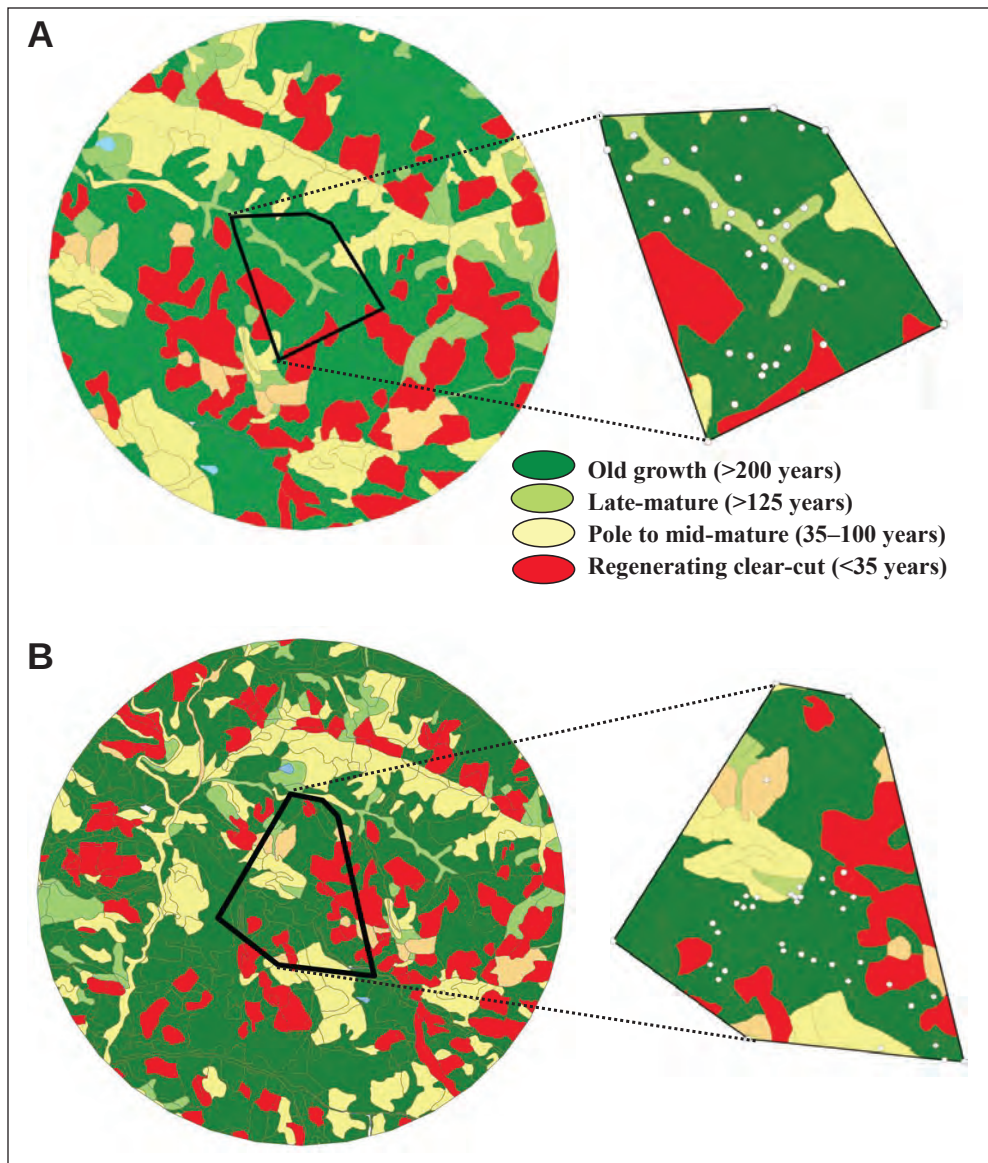


Figure 17—Home range position in the landscape, habitat composition, and within-home range habitat use by (A) a typical adult female and (B) a typical adult male Humboldt marten (*Martes caurina humboldtensis*). Home ranges represent 100 percent minimum convex polygons in nonserpentine forest habitat. Ninety-seven percent (38 of 39) of the adult females' and 77 percent (30 of 39) of the males' within-home range resting and active locations occurred in the core old-growth and late-mature riparian habitat patches (Slauson and Zielinski, unpublished data).

Humboldt marten home ranges and detection sites often include large patches (median >150 ha) of the most favored habitat: old-growth forest, old-growth in combination with late-mature forest, or serpentine habitat.

partial harvest, and shelterwood) appears to be increased risk of predation, as described in detail in the “Intraguild Predation and Interspecific Competition” section.

The home ranges of Sierra martens in largely unlogged forest landscapes averaged 300 to 500 ha for males and 300 to 400 ha for females (Simon 1980, Spencer et al. 1983). Limited telemetry data from Humboldt martens suggest that adult male home ranges ($n = 3$) are of similar size (300–400 ha) (Slauson 2015). Telemetry data and habitat selection analysis at Humboldt marten detection sites indicated that home ranges include large patches (median >150 ha) of the most favored habitat: old-growth forest, old-growth in combination with late-mature forest, or serpentine habitat (Slauson et al. 2007) (figs. 17, 18).

Landscape-Scale Effects on Habitat Use: Movement, Occupancy, and Population Dynamics

Habitat patterns and composition at the landscape scale affect the ability of martens to successfully disperse and find suitable home ranges, their survival and spatial occupancy dynamics, and ultimately, population size and persistence. The amount and spatial arrangement of high-quality habitat capable of supporting one or more home ranges, the distance between patches, and the quality of intervening habitat are key factors at the landscape scale (Chapin et al. 1998, Hargis et al. 1999, Kirk and Zielinski 2009).

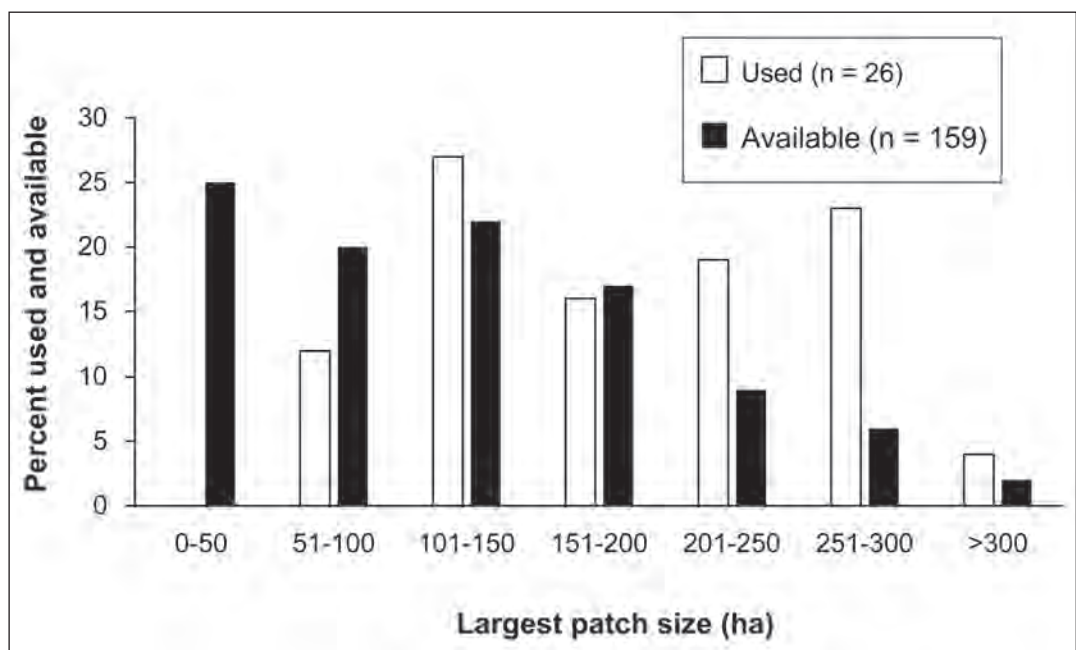


Figure 18—Use and availability of the largest contiguous patch of old-growth, old-growth plus late-mature, or serpentine habitat within a 1-km radius that encompassed locations occupied by Humboldt martens (*Martes caurina humboldtensis*) in California (Slauson et al. 2007).

Marten populations are sensitive to loss and fragmentation of high-quality habitat at the landscape scale. This is not to say that martens cannot persist on managed landscapes; with careful management to maintain and regenerate critical structures, and if certain thresholds are not surpassed, martens can be maintained along with timber production (Thompson et al. 2012). Where clearcut harvesting is practiced, reduced populations can be expected for ≥ 40 years if >25 to 30 percent of the forest is composed of regenerating stands (Chapin et al. 1998, Hargis et al. 1999, Poole et al. 2004, Potvin et al. 2000, Thompson and Harestad 1994). Martens are sensitive to the spatial distribution of suitable habitat and typically establish home ranges where ≥ 70 percent is composed of suitable habitat and include large patches (>150 ha) of suitable habitat in individual home ranges (Chapin et al. 1998, Potvin et al. 2000, Slauson et al. 2007). American martens appear more capable of tolerating partial harvest than clearcutting, but are very sensitive to the residual basal area of certain tree species, tree sizes, and canopy covers left after harvest (Fuller and Harrison 2005, Godbout and Ouellet 2008, Potvin et al. 2000). Threshold values for canopy cover, residual basal area, and species composition following timber harvest are ecoregion-specific and remain to be developed within the range of the Humboldt marten.

Beyond the direct impacts of habitat loss and fragmentation from timber harvest or severe wildfire, these modifications also affect martens indirectly by increasing the abundance of habitat generalist carnivores and raptors capable of preying on martens. Bobcats select for young regenerating clearcuts in the assessment area (Slauson 2018 and Wengert 2013) and are important predators on martens (Bull and Heater 2001, Slauson et al. 2014). Analysis of more than 400 bobcat scats identified brush rabbits and dusky-footed woodrats as the primary prey species in the bobcat diet in coastal California forests (Slauson N.d.). In the assessment area, dusky-footed woodrats are most abundant in young, regenerating even-aged stands (Hamm and Diller 2009). The diet and habitat associations of brush rabbits have not been studied in the assessment area, but their reliance on grasses, herbs, and disturbance-dependent shrubs (e.g., *Ceanothus* sp.) in their diets elsewhere (reviewed in Verts and Carraway 1998) suggest their abundance is closely tied to young stands regenerating from timber harvest or severe wildfire. Thus, both of the important prey species of the bobcat occur in early-seral forests in which bobcats should also be expected to occur and focus a high proportion of their hunting activities.

While bobcats select for and most frequently forage in young regenerating stands, they appear sensitive to the proportion of young regenerating forest at the

Marten populations are sensitive to loss and fragmentation of high-quality habitat at the landscape scale.

To develop effective strategies for Humboldt marten management and conservation, managers will have to consider landscape-scale habitat conditions and account for the direct and indirect effects of management alternatives, including the effects of habitat-mediated predation on martens.

landscape scale. In landscapes composed of a mix of 40- to 60-year-old regenerating stands and old-growth, or composed largely of unmanaged mid- and late-successional stands, bobcats were nearly absent (Slauson, in prep.). Elsewhere in North America, martens occupying remnant suitable portions of landscapes fragmented by logging experience higher predation rates and lower survival rates than martens occurring in more contiguous, unlogged landscapes (Potvin and Breton 1997, Raphael 2004, Thompson 1994). To develop effective strategies for Humboldt marten management and conservation, managers will have to consider landscape-scale habitat conditions and account for the direct and indirect effects of management alternatives, including the effects of habitat-mediated predation on martens.

Dispersal is the means by which marten populations maintain and expand their distribution and population size. Successful dispersal requires functional connections between habitat patches capable of supporting reproduction. Dispersal is also essential to maintain viable metapopulations, should that be the structure of marten populations. Johnson et al. (2009) found that in intensively logged landscapes, daily and total dispersal distances were reduced by approximately 50 percent, and that the success rate of juvenile martens dispersing to establish home ranges was reduced from 49 to 25 percent. In combination, reduced foraging efficiency in predominantly clearcut stands (Andruskiw et al. 2008), and increased predation risk in postlogging early-seral habitat may pose significant impediments for dispersing martens.

Given the energy demands of dispersal, foraging success is likely to influence dispersal movements. Dispersing martens use a search strategy that is not random or linear, suggesting they are responding to habitat cues and that landscape pattern likely influences movement trajectories (Johnson 2008). Search behavior during dispersal often involves sharp turning angles to avoid barriers or low-quality habitat and reversing direction to return to familiar areas (Johnson et al. 2009). In a local example, a dispersing juvenile female Humboldt marten moved along a strand of unmanaged stands of various seral stages, but repeatedly used a small (<50 ha) old-growth stand prior to returning to her natal area (Slauson and Zielinski 2009a). Also, two subadult males that made relatively long dispersal movements across intensively managed forest each finally established home ranges in areas with uncut forest stands or large numbers of residual structures (Slauson et al. 2014). In addition to the direct and indirect effects that habitat conditions can have on dispersal, natural and anthropogenic features—such as major rivers and highways—can influence both the decisions to cross and the outcome (e.g., survival or death) of those decisions. The combination of the well-documented behavior of avoiding entering habitats with reduced escape cover (e.g., Cushman et al. 2011) and the

number of Humboldt marten roadkill observed along U.S. Highway 101 in coastal Oregon (e.g., Zielinski et al. 2001) suggest highways may represent important filters for movement and dispersal. In addition, major rivers pose the additional challenge of the need for the disperser to successfully swim across open water which, at this time, has an unknown influence on both the probability that a disperser will decide to cross and survive. Overall, the assessment of conditions supporting dispersal will need to consider the combination of direct and indirect effects of habitat conditions on dispersers as well as how strong natural and anthropogenic features can act as filters or barriers to dispersal.

Contemporary Landscape Habitat Suitability

Slauson et al. (2018) developed a landscape-scale habitat suitability model for marten for the extent of the assessment area where survey data were available up to 2010 and applied the model to the full extent of the assessment area (fig. 19). The model was developed using the combination of variables that best described the distribution of marten detection/nondetection survey data. The survey dataset consisted of 1,159 surveys using protocols with sufficient survey effort to yield high probabilities of detection at locations from public, private, and tribal lands distributed from Mendocino County, California, north to Coos County, Oregon, that were surveyed between 1990 and 2010. A total of 29 predictor variables from six categories were considered: climate, topography, linear features (roads and streams), forest structure and composition, landscape arrangement, and disturbance. Variables were assessed at three spatial scales using “moving windows” with 500-, 1000-, and 3000-m radii to assign each 30- by 30-m pixel a value representing the variable characteristics within the windows.

The forest structure and compositional variables were derived from the gradient nearest neighbor (Ohmann and Gregory 2002) gridded vegetation dataset, which provided a seamless source for calculating the proportion of the area of the moving window at each scale for 13 forest structural and compositional variables. Candidate multivariate models were developed based on hypothesized positive and negative relationships between marten occupancy and combinations of the variables.

The top ranked models that best fit the data consistently included three variables: old-growth structural index (OGSI) (at the 1-km scale), serpentine habitat (at the 3-km scale), and precipitation (at the 3-km scale) (Slauson et al., n.d.). Higher average OGSI values at the 1-km scale and higher areas of precipitation at the 3-km scale were positively associated with marten occupancy. The OGSI is an average of four separate indices representing stand age and four structural features: number of large trees (>100 cm d.b.h.), large snags (>50 cm d.b.h. and >15 m tall), volume of

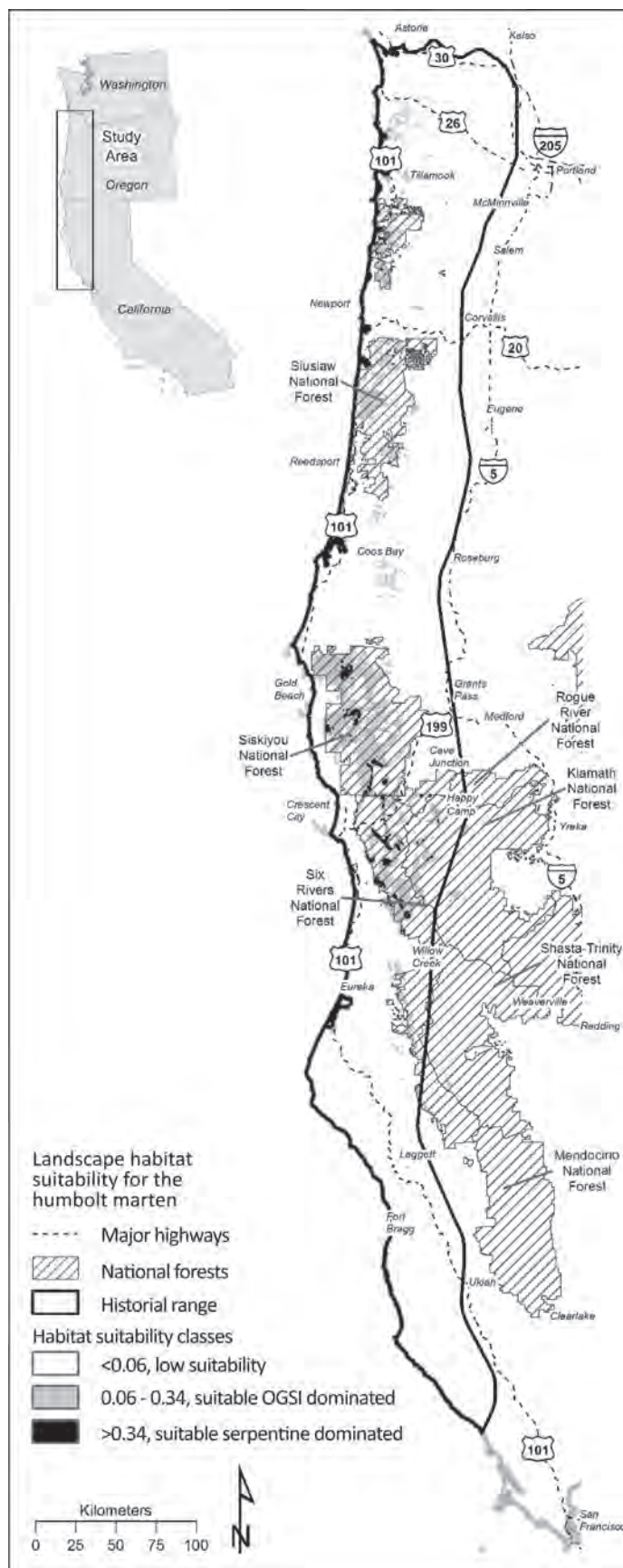


Figure 19—Landscape habitat suitability for the Humboldt marten (*Martes caurina humboldtensis*) throughout its' historical range in coastal California and coastal Oregon (Slauson et al., n.d.). OGSi = Old-growth structural index.

large snags, and tree size diversity (Spies et al. 2007). Small and moderate amounts of serpentine habitat at the 3-km scale were positively associated with marten occupancy, but large areas were negatively associated. In summary, the top models identified two habitat types: mesic forest habitat with high OGSi values (most widespread habitat type) and mesic forest habitat on serpentine soils with low OGSi values (this habitat type occurs in <5 percent of the historical range) (fig. 19).

The final model averaged the coefficients of the top three models and had an overall correct classification rate of 83 percent, with greater skill at correctly classifying marten detection locations (91 percent of 75) than nondetection locations (82 percent of 1,078) and a true skill statistic of 0.73 (with 1.0 being best) (Allouche et al. 2006). Model predictions were stable when evaluated with 5 by 5 cross-validation. The model did not predict well for the shore pine habitats in central coastal Oregon where survey data were not available during initial model development but martens are known to occur based on roadkill and more recent survey results. While this discrepancy will need to be addressed in the next model revision, shore pine habitat represents a rare habitat type (<3 percent of historical range), that can likely be modeled similar to how serpentine habitat was modeled; thus shore pine habitat type is accounted for in this assessment.

The final model, when applied to the full extent of the assessment area, predicts that suitable habitat occurs in <15 percent of the historical range and 91 percent of all detections occur in these areas. Three general areas with large patches of high-suitability habitat were identified: one in northwestern California that supports the only known populations for the state, and two in Oregon, one on the central coast and one in the south coastal area (figs. 19 and 20). The model also predicted some habitat that may provide connectivity between the California and south coastal Oregon populations, but identified little habitat between the south and central coastal Oregon populations.

The model described above was constructed and evaluated prior to a number of new detections of Humboldt martens in California during 2011–2015. These more recent detections provided an opportunity to evaluate the accuracy of the model's predictions. The model correctly classified 73 percent (36 of 49) of these new detection locations: 17 of 18 new detection locations in the 2012 population monitoring effort, 4 of 9 new detection locations in the area just south of U.S. Highway 199, and 15 of 22 areas used by radio-collared individuals in the managed forest landscape west of the main California population (Slauson et al. 2014). The six misclassified marten detection locations from the first two survey efforts occurred an average of 825 m from a habitat patch identified as suitable in the model. The seven misclassified marten-use areas from the dispersal study had approximate use

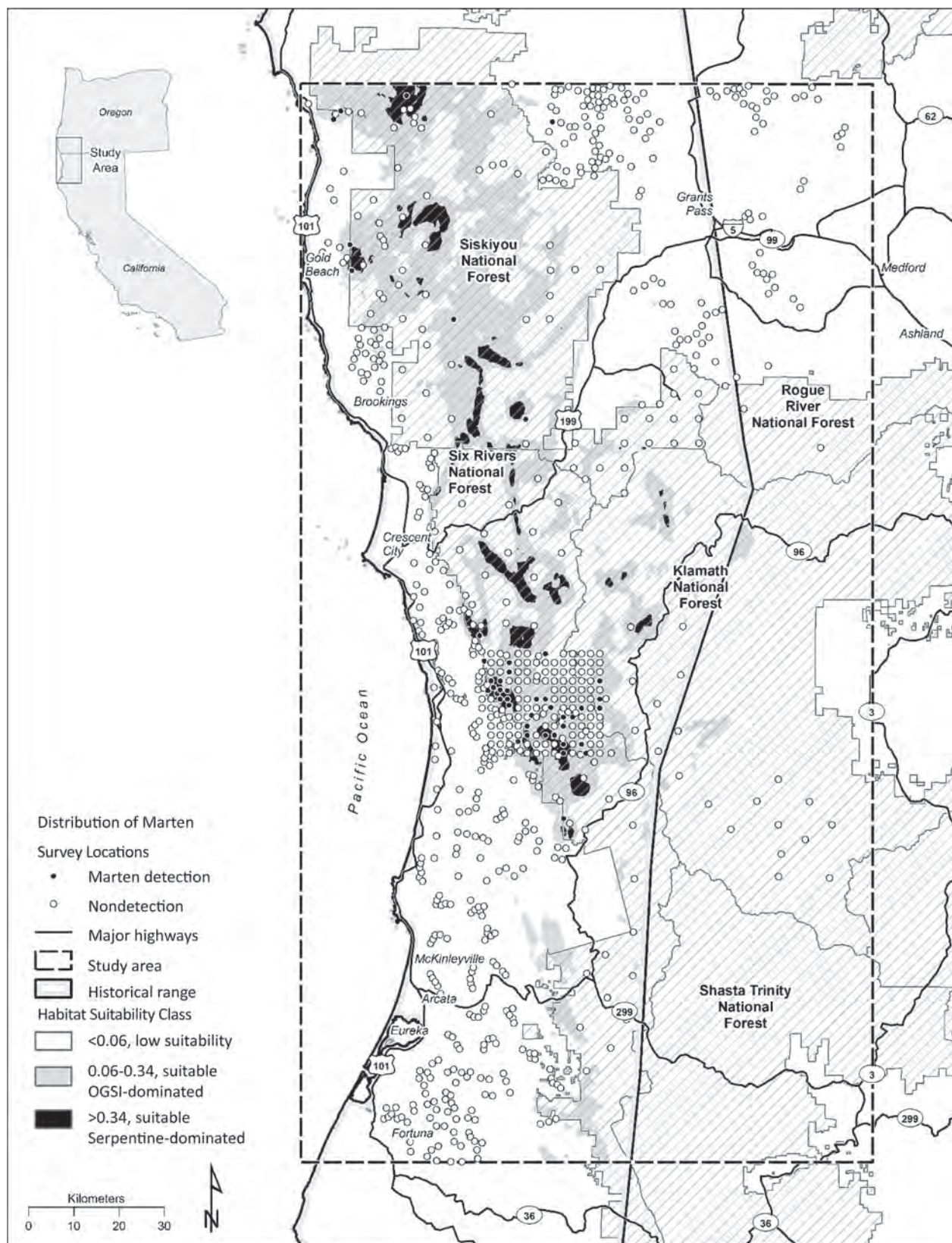


Figure 20—Distribution of marten detection/nondetection survey data through 2010, and resulting landscape habitat suitability model for the Humboldt marten (*Martes caurina humboldtensis*) in coastal California and Oregon (Slauson et al., n.d.). OGSi = old-growth structural index.

area centroids that occurred an average of 1623 m from a modeled suitable habitat patch. Marten locations (13 of 49, 27 percent) that occurred outside of modeled suitable habitat patches represent surveys conducted during the dispersal season, and therefore may represent the presence of nonresident individuals, or individuals that attempted to establish home ranges but were known to have died in these areas. In sum, the landscape habitat suitability model performed well at identifying locations where the new detections occurred. As such, it should provide a strong foundation for conservation planning. However, we recognize that as new information is gathered, updates to the model and reinterpretation of model outputs may be required.

Implications for Conservation

- Recent genetic evidence indicates that coastal California and coastal Oregon marten populations represent a single evolutionary unit. To conserve the genetic diversity expressed in this population, it should be managed to maintain and restore the population connectivity and gene flow within the current (and ideally the historical) range of this subspecies.
- Humboldt martens occur in a few small, isolated populations. The distribution of the Humboldt marten has significantly declined in both California and Oregon. Only four geographically disjunct populations are known to currently exist. The largest California population was estimated to be at <100 individuals in 2012 (Slauson 2012, Slauson et al. 2009a); its small size puts it at risk of extirpation. The uncertainty about the sizes of Oregon populations—which are likely to be smaller than the largest California population, based on the current knowledge of the sizes and distributions of occupied habitat patches—is also of significant concern. Efforts to limit future reductions and increase population size and connectivity would be a valuable contribution to the conservation of the species.
- The majority of key prey species for martens in the assessment area rely primarily upon conifer cone crops and the fruiting bodies of ectomycorrhizal fungi as their food sources. In addition, dense shrub cover can influence the abundance of seasonally important prey species. Management practices that maintain and enhance these resources are likely to improve foraging habitat for martens.
- Juvenile dispersal distance and successful home range establishment can be significantly affected by landscape condition. Long-term planning and management that affects functional connections between patches of suitable habitat will have an effect on population size and connectivity.

- Adult and juvenile survival are the most important demographic parameters affecting stability and growth of marten populations. As such, individual or cumulative factors that reduce or increase survival rates represent significant impacts (negatively or positively, respectively) on population growth and persistence.
- Larger bodied carnivores, especially habitat generalists, are the most common predators of martens across their range in North America, and predation is expected to be a primary driver of survival, which in turn is a very influential predictor of marten population growth and persistence. Predation rates on marten populations are highest in landscapes that have been fragmented by intensive logging methods, including clearcut, shelterwood, and closely related silvicultural systems. The bobcat has been identified as the most common predator of the California population of Humboldt martens. Bobcats are strongly associated with harvested stands ≤ 30 years of age, but are much less common in landscapes where a high proportion of harvested stands are ≥ 40 years old. Indirect effects of management actions on marten predation risk should be assessed during development of landscape-scale forest management and restoration plans.
- Most known locations for Humboldt martens occur on productive soil types, where martens show strong selection for large patches of old-growth conifer-dominated forest with dense ericaceous shrub layers. However, they also can use more open forest types with dense shrub layers on low-productivity soil, such as shore pine and transitional shore pine-hemlock-Douglas-fir forest types or forest types on near-coast serpentine soils. Recently, Humboldt martens on the edge of the current population distribution have been found in a mosaic of stands that were harvested several decades ago and include large-diameter live and dead conifers and live hardwoods. The effects these managed and low-productivity habitats may have on marten population performance, survival, and reproduction is unknown. More information is warranted to understand the role these habitat types could play in supporting marten conservation objectives.
- Dense, spatially extensive shrub layers are a consistent habitat component at most locations where Humboldt martens have been detected in coastal California and coastal Oregon. This unique habitat association has not been described elsewhere in the distribution of either North American marten species. These shrub layers are dominated by shade-tolerant ericaceous

species. Retention and regeneration of shade-tolerant ericaceous shrub layers is likely to have important consequences for marten habitat suitability and population conservation.

- Marten population persistence is affected by habitat conditions at multiple scales. Forest management and restoration planning that includes considerations for marten habitat and population conservation will benefit from developing management and restoration actions for resting/denning features and surrounding stands, while maintaining suitability at the home range and landscape scales. Indirect effects of forest management that influence the distribution and abundance of marten predators is also an important consideration in forest management and restoration planning for Humboldt martens.

Research and Management Needs in the Assessment Area

- Determine the phylogenetic relationships for all Pacific marten populations in California and Oregon. This information will better identify how extant populations could be managed to preserve their genetic uniqueness within their respective ranges.
- Continue to survey for Humboldt martens in forested habitats at the margins of the known populations. Use consistent survey and monitoring methods to determine population distribution, abundance, and trends throughout their range.
- Quantify amounts and thresholds of marten denning habitat at the home range scale. Develop spatially explicit models of denning habitat distribution to inform habitat conservation, maintenance, and restoration planning and implementation.
- Estimate demographic parameters, including fecundity and stage-specific survival, to support the evaluation of management and conservation actions. For fecundity estimation, both pregnancy and kit production rates are needed to better understand the relationships between these two metrics of reproduction. Also, determining rates of reproductive decline among aging adult females would improve population modeling.
- Determine the landscape-scale habitat characteristics that promote successful dispersal for Humboldt martens. Identify effective approaches for maintaining or improving the conditions capable of promoting successful dispersal at both the stand and landscape scales.
- Describe the habitat selected by important marten prey, and identify stand-level management actions that can increase their abundances.

- Continue research on predators of the Humboldt marten, habitat conditions that support them, and characteristics of kill sites. Strengthen the understanding of relationships between various types of silvicultural management and key marten predators. Identify stand- and landscape-level management actions that would reduce predation risk to martens.
- Use existing information to evaluate characteristics such as timing, speed, and distance, and environmental factors contributing to successful dispersal. Incorporate findings into an evaluation of the feasibility of assisted dispersal.
- Evaluate relationships between Humboldt marten distribution and various timber and fuels management practices at the stand and landscape scales. Identify silvicultural practices that increase habitat suitability for martens and their prey. Develop canopy-cover, basal-area, and tree-species composition thresholds for partial and selection harvest and thinning that are compatible with maintaining martens and shortening the time for restoring habitat suitability.
- Increase understanding of the linkages between marten fitness parameters and multiple-scale habitat characteristics. Continue to refine the analytical foundation for evaluating the effects of management and conservation actions on marten population size and viability.
- Evaluate the risk of inbreeding and depressed fitness for the population sizes that currently exist. If warranted, identify alternatives for improving gene flow and effective schedules for implementation.
- Continue to evaluate the impacts of rodenticides on Humboldt martens, explore actions that are effective in reducing their impacts to martens and their prey, and share information with law enforcement and regulatory agencies as appropriate.
- Continue to update and improve the accuracy of the landscape habitat suitability model. Incorporate influences of important predators on the habitat suitability for martens.

Chapter 5: Development of the Conservation Strategy Foundation

In this section, the Humboldt Marten Conservation Group (HMCG) describes the process for developing the conservation strategy foundation (fig. 21). Each step of the process uses the scientific information in previous sections to identify key conservation actions and research needs. Then each conservation action is prioritized within a biologically relevant timespan for marten populations. The HMCG expects that the overall conservation strategy will be further developed over time with the completion of additional strategy modules, such as the Habitat Management Guide and Population Monitoring Protocol (see the “Next Steps” section). The intent is for this strategy to be a dynamic product, subject to updating and improvement as new information is gathered and synthesized (fig. 21).

Strategy Goal, Guiding Principles, and Approach

To establish a solid scientific foundation for the development of the conservation strategy, the HMCG has developed an overall goal—to establish self-sustaining, interacting populations of Humboldt martens throughout their historical range—that defines the overall direction for the strategy, along with guiding principles, and an approach for meeting the goal. The guiding principles set the rules by which the strategy will be developed and, if needed, amended, and the approach provides the details on how we will achieve our overall goal.

In interpreting the science to identify effective conservation options, the HMCG applied the following “best practices” guidelines to develop the conservation strategy:

- The HMCG used the best available scientific information on martens. Where available, information from studies conducted within the assessment area was used. When using information collected outside the assessment area, the HMCG relied primarily on findings that were consistent across different forest ecoregions.
- The HMCG used the principles of conservation biology, landscape ecology, and forest ecology as the foundation for the conservation strategy. Guiding principles of conservation biology include the recognition that martens in the assessment area exist in a metapopulation structure (a group of spatially separated populations of the same species that interact via dispersal) and this structure is currently in a nonequilibrium state. The HMCG defines nonequilibrium as the population processes (e.g., occupancy of suitable habitat, population size fluctuations, dispersal rates) not currently being in a

The HMCG's overall goal—to establish self-sustaining, interacting populations of Humboldt martens throughout their historical range.

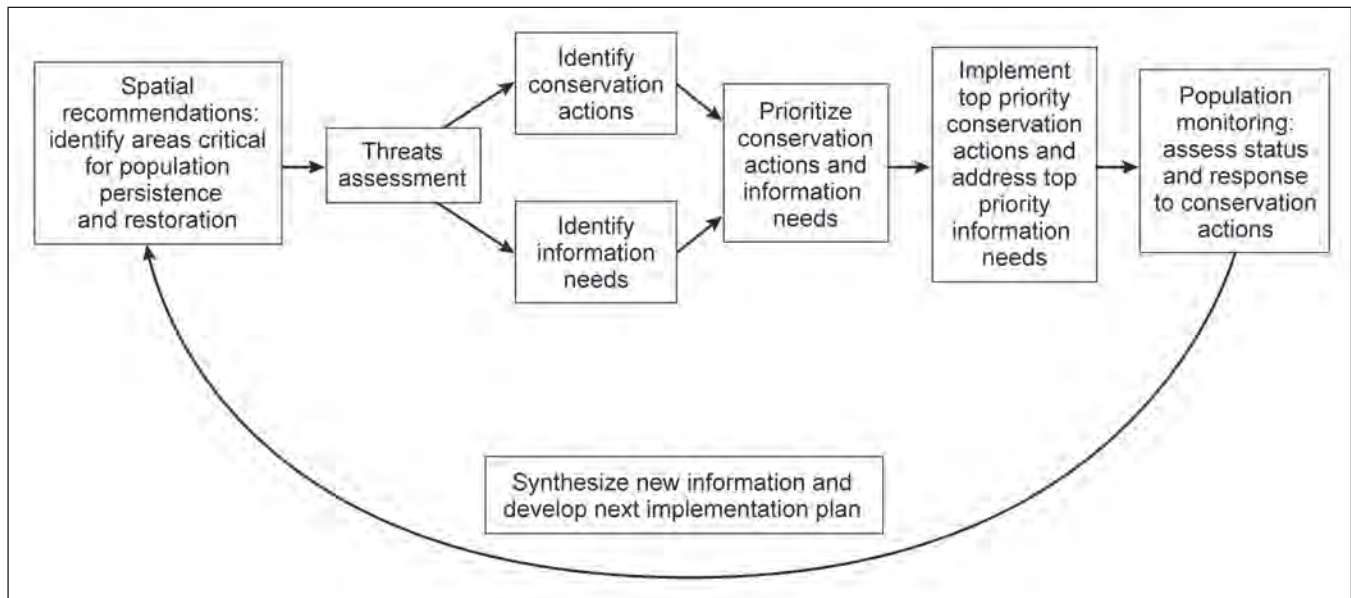


Figure 21—Conceptual model of the development and implementation steps for the Humboldt marten conservation strategy.

steady state owing to a combination of both natural and anthropogenic factors. Guiding principles of landscape ecology include how quality, amount, and spatial arrangement of habitat affects both individuals and subpopulations. In addition, functional habitat connectivity within and between subpopulations will be necessary for the successful movement of individuals to support population persistence and gene flow. Guiding principles of forest ecology include managing marten habitat and habitat elements within their historical ranges of variability and natural disturbance regimes where possible. In addition, many important habitat elements naturally develop over decades to centuries and involve growth, disturbance, and decay processes.

- The HMCG addressed four spatial scales: (1) landscape, (2) home range, (3) stand, and (4) individual habitat structures (microscale). The conservation strategy foundation is based on these four spatial scales in which martens use habitat, leading to a spatial template to guide the application of conservation actions. The HMCG identified and prioritized conservation actions and information needs anticipated over the next 15 years (see “Timing” in the “Classification of Potential Threats” section for justification).

State of the Science for Supporting the Development of a Conservation Strategy

The current state of scientific knowledge for the Humboldt marten continues to develop; however, the HMCG recognizes that management and conservation actions to guide the maintenance and expansion of martens and their habitat are needed promptly to take steps toward attaining our overall strategy goal. The HMCG recognizes that the development of the conservation strategy will occur in stages as new science emerges. Despite some information gaps, The HMCG has determined that there is sufficient scientific information at this time to develop a conservation strategy foundation that will establish the overall goal, guiding principles, and approach for the strategy and identify its core components, the conservation emphasis areas (see below). In addition, the conservation strategy foundation includes a threats assessment, conservation actions to ameliorate significant threats, and next steps and information needs to guide the acquisition of new science to support the development of future strategy components and conservation actions. For example, the HMCG recognizes the need for new science to develop a Habitat Management Guide (see the “Next Steps” section on page 94) and the next module of the strategy.

Overall Strategy Approach

This conservation strategy uses a three-pronged approach:

- **Protect** existing populations and currently suitable habitat.
- **Reestablish** populations in areas of currently suitable but unoccupied habitat.
- **Restore** habitat conditions in specific areas to increase population size, distribution, and connectivity.

Conservation actions include maintaining and improving habitat for survival and reproduction in existing and potential population areas, along with maintenance and restoration of functional habitat connectivity between areas of currently suitable habitat. Reestablishment of martens in areas that are suitable, but unoccupied, may reduce overall population impacts, should occupied areas be lost in stochastic events such as severe wildfire or disease outbreaks. Concurrently, landscape-scale habitat restoration efforts that increase the amount and improve the distribution of suitable habitat will (1) support long-term expansion and viability of reestablished populations, and (2) improve long-term viability of extant populations through exchange of dispersers and gene flow.

The conservation strategy is primarily based on identification of spatially explicit conservation emphasis areas where conservation actions appear to have the greatest potential to meet the overall strategy goal.

To make the approach for the overall strategy operational, the HMCG:

- Identified locations that serve important functions in supporting, securing, and restoring marten populations.
- Identified priorities for each location and actions that are likely to move each location toward the desired conditions.
- Identified the threats for each location that could inhibit or reverse progress toward desired conditions, and actions that could mitigate against such impacts.

Conservation Emphasis Areas

The conservation strategy is primarily based on identification of spatially explicit conservation emphasis areas where conservation actions appear to have the greatest potential to meet the overall strategy goal. Conservation emphasis areas fulfill the three-pronged strategy approach by:

- Protecting existing populations and currently suitable habitat in order to anchor the existing populations—through **extant population areas (EPAs)**.
- Reestablishing populations in areas of currently suitable, but unoccupied, habitat—through **population reestablishment areas (PRAs)**.
- Restoring or improving habitat conditions to increase connectivity between existing populations and the number of sites able to support populations—through **landscape connectivity areas (LCAs)**.

In mapping the conservation emphasis areas, the HMCG relied on recent and verifiable marten detections and the landscape habitat suitability model (figs. 19, 20). The landscape habitat suitability model relies on the statistical relationships between marten survey results and attributes of vegetation and the physical environment represented in the model (see the “Contemporary Landscape Habitat Suitability” section). The HMCG recognizes that all models are caricatures of reality and are only as good as the data used to create them; the marten model is no exception. As described earlier, the model is better at correctly identifying the locations where martens were detected than locations where they were not detected, and puts the emphasis on higher accuracy for detections, as is desired for habitat models for species of conservation concern (Franklin and Miller 2010). Sufficient information presently exists to identify areas of relatively high habitat suitability (via the output of the habitat suitability model) and general principles appropriate for habitat management.

The HMCG suggests that it is prudent to recommend a demarcated set of geographical areas representing the state of knowledge about Humboldt martens in California through 2016, but recognizes that new information and conservation opportunities may require updating the boundaries of these areas and consideration of other areas not currently emphasized.

Conservation emphasis areas are intended to represent the areas with the greatest current potential to achieve the overall marten conservation goal, to establish self-sustaining, interacting populations throughout their historical range. There are three categories of conservation emphasis areas:

- **Extant population areas**—The distribution of extant populations, identified to protect existing populations and adjacent suitable habitat in order to anchor the existing populations.
- **Population reestablishment areas**—Unoccupied habitat currently suitable to support ≥ 5 female marten home ranges, identified to reestablish populations in areas of currently suitable, but unoccupied, habitat.
- **Landscape connectivity areas**—Habitat adjacent to or between any combination of the two areas listed above, but currently unsuitable or of low suitability, identified to restore or improve habitat conditions to increase connectivity between existing populations and the number of sites able to support populations.

In the following sections, the HMCG describes the origin, proposed location, and intended function of the conservation emphasis areas. The HMCG recognizes that land managers have multiple objectives to consider when implementing their land use plans, and the strategy presented herein does not impose any additional planning criteria. Rather, the HMCG's primary intention with the strategy is to inform the objectives of managers when working in and near these areas as to the potential consequences of their actions with regard to Humboldt marten conservation. Note that there is variability in vegetation, topography, and other environmental factors that cannot be accounted for in mapping at the scale of the conservation emphasis areas. To help guide the design and evaluation of projects, local managers will need to apply methods for evaluating habitat management actions at finer spatial scales. The forthcoming Habitat Management Guide (see the "Next Steps" section) will illustrate a range of conditions suitable for martens at scales from the stand level to home ranges, which will provide the linkage between the conservation emphasis areas and project-level guidance that managers can use in evaluating current habitat suitability and potential effects of management actions.

Management actions that maintain or enhance habitat suitable for marten occupancy and increase the capability to support reproduction and survival will be consistent with the goal of the strategy.

Currently suitable habitat, capable of supporting both reproduction and survival, will have the most significant value for martens, and where it exists, receive the highest priority for maintenance and protection. Management actions that maintain or enhance habitat suitable for marten occupancy and increase the capability to support reproduction and survival will be consistent with the goal of the strategy. Meanwhile, areas adjacent to habitat suitable for reproduction and survival represent strategic opportunities for habitat restoration or improvement and connectivity to other areas of suitable habitat. Within each conservation emphasis area category, strategic habitat restoration areas can be identified to:

- Increase the amount of suitable habitat capable of supporting individual home ranges; or
- Increase functional habitat connectivity between patches of currently suitable habitat.

The HMCG expects that future tools such as the Habitat Management Guide (see the “Next Steps” section) will help identify areas where potentially adverse actions, such as fuels reduction treatments or timber harvests, can be strategically located to avoid marten habitat or minimize negative effects on suitable habitat while meeting the overall intent of such projects. The HMCG expects that management actions, including habitat maintenance, habitat improvement or restoration, and connectivity improvement could occur in each of these conservation emphasis areas. The forthcoming Habitat Management Guide will help managers determine the most appropriate locations for and the appropriate size of areas to target for implementing actions to support the overall strategy goal.

Area statistics for the conservation emphasis area are presented in table 1. The HMCG proposes initial locations for each of the three types of conservation emphasis areas in California and EPAs in Oregon but realizes that landowners, agencies, and possibly other stakeholders will ultimately determine the actual application of conservation emphasis areas and habitat management actions recommended by this conservation strategy.

Extant Population Areas

EPAs include the contemporary distribution of marten populations in the assessment area, plus areas of suitable habitat extending 2 km from verified marten locations at the periphery of each population. Contemporary distribution is defined by the locations where verifiable records of martens occurred from 1980 through 2016, including survey station detections and telemetry locations. However, the margins of the depicted EPA polygons (fig. 22) are based on judgment and the aforementioned landscape habitat suitability model, and should not be interpreted as

Table 1—Area statistics of conservation emphasis areas (CEA) in California

Conservation emphasis areas	Total size	Percentage of California historical range	Amount of suitable habitat ^a	
			Occupancy	Percentage of each CEA
	<i>Hactares</i>		<i>Hactares</i>	
Extant population areas:				
North coastal California	81,182	3.9	65,616	80.8
California-Oregon border	17,615	0.9	15,366	87.2
Population reestablishment areas:				
Smith River	82,583	4.0	71,065	86.1
Middle Klamath	65,389	3.2	52,104	79.7
Redwood and Prairie Creek	143,003	6.9	74,563	52.1
Northern Redwood State Parks	14,419	0.7	981	6.8
Landscape connectivity area:				
Lower Klamath	33,977	1.6	1,817	5.3
Total	438,169	21.2	—	—
Undefined areas	1,625,684	78.8	—	—

^a Amount of suitable habitat for occupancy includes the total acreage of the two highest categories (high and moderate) of modeled habitat suitability (green and red in fig. 24)

formal boundaries. The survey data available to delineate the boundaries for extant populations varied considerably across the assessment area. The HMCG aggregated marten locations into EPAs by connecting locations within 5 km of each other (the typical marten dispersal distance, as described in the “Biological Information” chapter) with the shortest possible line through suitable habitat (as defined by the landscape habitat suitability model). If the total number of detections in an isolated cluster was <5, or a cluster of detections was separated by >5 km from other detection locations, they were not identified as an EPA owing to insufficient evidence that the population is self-sustaining. Based on the distributions of recent survey efforts and verifiable marten detections, we identified four EPAs in the assessment area: (1) North Coastal California, (2) California-Oregon Border, (3) South Coastal Oregon, and (4) Central Coastal Oregon (fig. 22). The EPAs in California are based on a significant amount of survey information and are regarded as having a high degree of certainty in the delineation of their boundaries. The EPAs in Oregon are based on a lower level of survey information at the time of their creation and therefore have a lower degree of certainty. However, the EPAs in Oregon are provisionally identified to guide the strategic survey efforts necessary to refine their distribution, estimate population sizes, and identify where martens or suitable habitat currently occur.

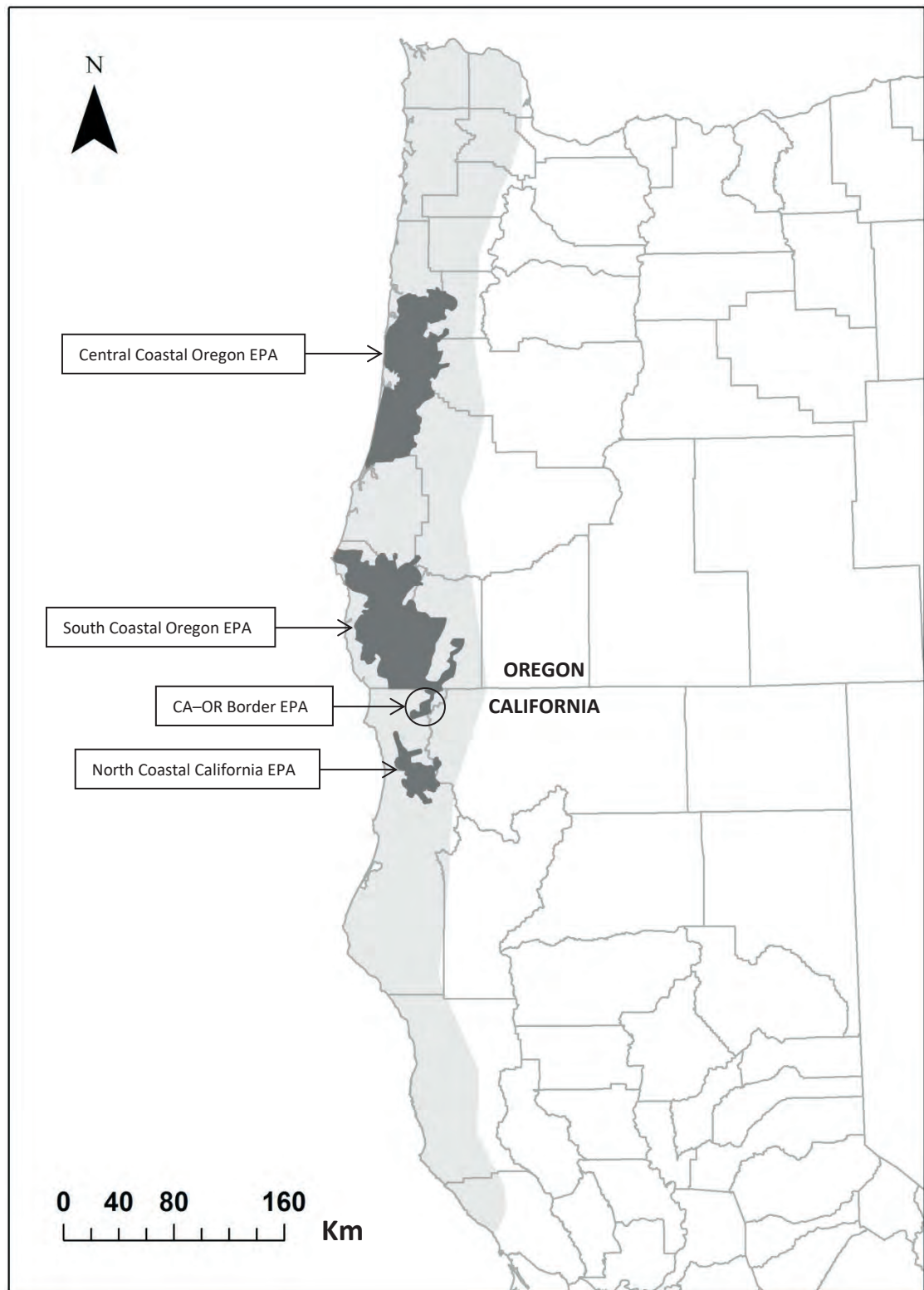


Figure 22—Locations of the four extant population areas (EPAs) of Humboldt martens (*Martes caurina humboldtensis*) in the assessment area. The two extant population areas in Oregon are provisional until additional distributional data are obtained to better guide their delineation.

North Coastal California EPA—

Available survey data for this EPA were much more extensive than for other EPAs. More than 600 verifiable locations of marten occurrence, including detections and radiotelemetry locations, were buffered by 2 km and connected to produce an EPA of 81 200 ha (fig. 23). The North Coastal California EPA includes the watersheds of South Fork of the Smith River, Blue Creek, Bluff Creek, Camp Creek, Cappell Creek, Pecwan Creek, Slate Creek, and Rock Creek, within Del Norte, northern Humboldt, and western Siskiyou Counties.

The administrative units responsible for land or species management in the North Coastal California EPA are the California Department of Fish and Wildlife, Green Diamond Resource Company, Klamath National Forest, Six Rivers National Forest, and the Yurok Tribe.

California-Oregon Border EPA—

The first detection of a marten in this EPA occurred in 2011. Subsequent survey efforts from 2012 through 2014 detected martens at five additional locations east of U.S. Highway 199 near the California-Oregon border in northeastern Del Norte County (fig. 23), on the Six Rivers National Forest and adjacent private lands. The spatial extent and number of martens represented by this EPA are currently unknown.

One additional area in California, Prairie Creek Redwoods State Park, had one or two verifiable marten detections in the same general area each year from 2009 to 2013 but none since. These detections, represented by two black dots outside the EPA in figure 23, were approximately 10 km west of the nearest marten location within the North Coastal California EPA and were insufficient in number to be considered a population using our criteria. Determining the number, sex, and ages of martens currently present in Prairie Creek Redwoods State Park is an important information need.

South Coastal Oregon EPA—

The majority of contemporary detections of martens in the South Coastal Oregon EPA occur in Curry County, both north and south of the Rogue River, on the Rogue River-Siskiyou National Forest (figs. 6 and 22). A single verified detection exists for Cape Blanco State Park (Moriarty et al. 2016), and unverified sightings were reported from Humbug Mountain State Park in the late 1990s. Two detections exist from western Josephine County, one of which occurred on Medford District BLM lands. Most of this EPA was designated based on the distribution of suitable habitat. The spatial extent and number of martens represented by this EPA are currently unknown.

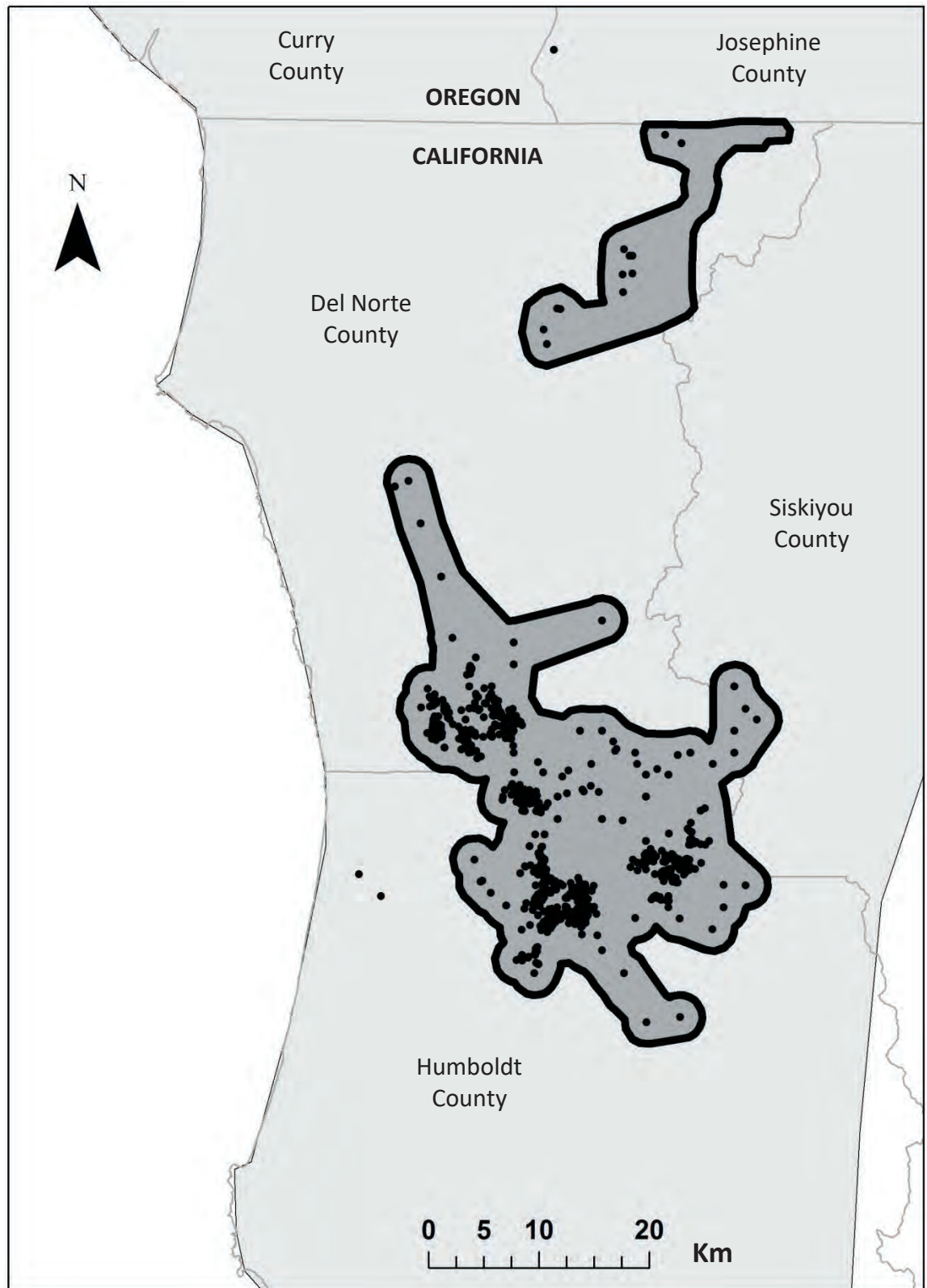


Figure 23—Location of the North Coastal California and California-Oregon Border extant population areas (dark gray polygons) for Humboldt martens (*Martes caurina humboldtensis*) in California. Marten detections are indicated as solid black circles.

Central Coastal Oregon EPA—

The majority of contemporary detections of martens in the Central Coastal Oregon EPA are from a combination of roadkill locations; survey detections; and, most recently, radiotelemetry locations from west of U.S. Highway 101 in coastal dune forest habitats in northwestern Coos, western Douglas, and western Lane Counties (fig. 6). Single trapping, roadkill, and incidental capture records occur west of U.S. Highway 101 in this EPA; and much of the EPA west of U.S. Highway 101 was delineated based on the presence of suitable, but heavily fragmented, habitat. The largest, most-contiguous patches of suitable habitat in this EPA have yet to be thoroughly surveyed. The spatial extent and number of martens represented by this EPA are currently unknown; however, in 2016, fewer than 63 individuals were estimated to occupy the dune forest habitat west of U.S. Highway 101 (Linnell et al., n.d.).

Population Reestablishment Areas

PRAs include habitat that currently appears suitable, but is not occupied by a marten population, or that has too few individuals (<5 females) or detections (<5 independent locations) to be considered as currently supporting a self-sustaining population. To be considered a PRA, sufficient suitable habitat (≥ 1500 ha) was present to support ≥ 5 female marten home ranges. We used a minimum of five female home ranges to define the minimum criterion for identifying a PRA because martens are rarely reliably detected in areas without the presence of habitat capable of supporting several reproducing individuals. The HMCG acknowledges that the exact number of female home range areas necessary to support a viable population is unknown and is dependent on factors (e.g., proximity to other areas supporting reproduction) other than the number of female home ranges. The HMCG assumes that areas with enough suitable habitat to support ≥ 5 female home ranges represent a reasonable minimum for considering an area as a candidate for population reestablishment. The HMCG identified PRAs using the landscape habitat suitability model (see the “Contemporary Landscape Habitat Suitability” section) and by recognizing additional large areas with high old-growth structural index (OGSI) value (Spies et al. 2007). The OGSI is a composite index from gradient nearest neighbor analysis (Ohmann and Gregory 2002) that integrates stand age, density of large conifers, diversity of tree sizes, density of large snags, and volume of down wood (Spies et al. 2007). Old-growth structural index, high rainfall areas, and serpentine habitat were the three variables included in all top landscape habitat suitability models (Slauson et al. 2018). However, the habitat model valued areas with high OGSI less when it occurred at lower elevations. This is most likely due to the combination of few contemporary marten detections at low elevations, where there

is a more extensive legacy of intensive forest management, rather than a biological relationship with marten habitat with high OGSi at low elevations. The majority of the assessment area is composed of nonserpentine habitat types (>90 percent), and marten detections at nonserpentine sites had the strongest association with high OGSi values. Therefore, we also used OGSi measured at the 1-km scale as a stand-alone variable to provide a more generalizable means for evaluating current habitat conditions than the full landscape habitat suitability model for delineating PRAs.

The HMCG identified PRAs in California but had insufficient detection data to identify PRAs in Oregon. Ideally, future survey efforts will yield sufficient data to establish PRAs in Oregon.

In northern coastal California, the HMCG identified four PRAs (fig. 24), based largely on the presence of contiguous areas of suitable habitat as predicted by the landscape habitat suitability model (fig. 24). The HMCG also included several large patches of low-elevation forest with high OGSi values that were not recognized by the model (fig. 24). For example, the HMCG included an area of old-growth habitat in Redwood National and State Parks on the coast west of the North Coastal California EPA.

The Smith River PRA (fig. 24) is adjacent to the northern border of the North Coastal California EPA and has connectivity to the South Coastal Oregon EPA (fig. 24). This PRA represents 4 percent of the historical range of the Humboldt marten in California (table 1). Based on the landscape habitat suitability model, over 86 percent of the Smith River PRA is capable of supporting marten occupancy (table 1).

The Northern Redwood State Parks PRA (fig. 24) is adjacent to the northern margin of the North Coastal California EPA. This is the smallest PRA (<1 percent of the historical range in California), but is composed primarily of low-elevation habitat with high OGSi values and includes a large block of habitat currently being managed to accelerate recruitment of old-growth forest characteristics. This PRA may eventually influence the movement of martens between the California and Oregon EPAs along the narrow western north-south corridor of currently suitable habitat (fig. 24).

The Middle Klamath PRA (fig. 24) is adjacent to the northeastern edge of the North Coastal California EPA and is located at the northeastern-most portion of the historical range in California. Over 79 percent of this PRA is predicted to be suitable habitat (table 1). However, much of the habitat in this PRA is outside the influence of the typical fog zone and thus may support fewer areas with the mesic habitat characteristics consistent with occupied marten sites in the neighboring North Coastal California EPA.

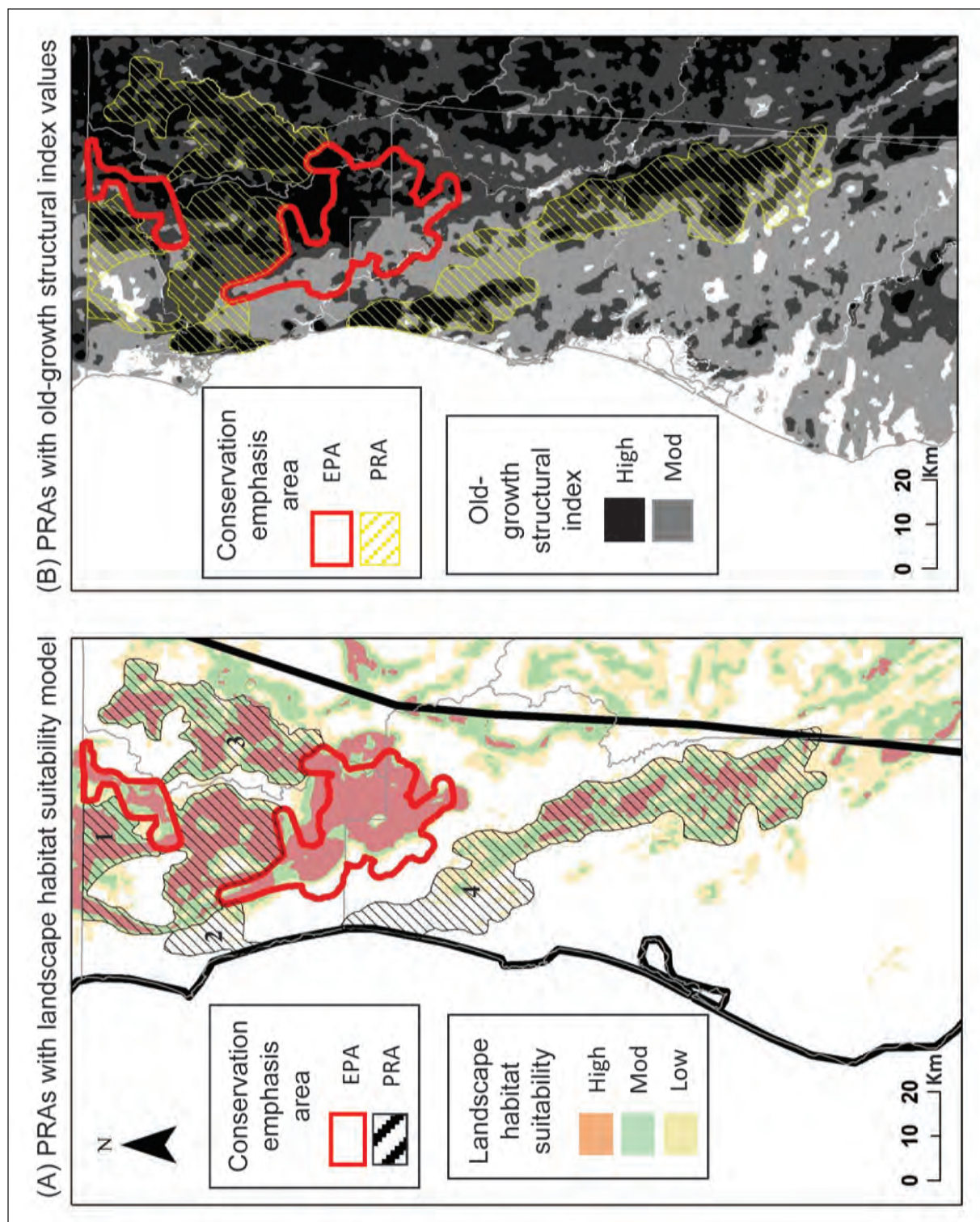


Figure 24— Locations of the four population reestablishment areas (PRAs) for Humboldt martens (*Martes caurina humboldtensis*) in California depicted with modeled habitat suitability (A) and old-growth structural index (B): (1) Smith River PRA, (2) North Redwood State Parks PRA, (3) Middle Klamath PRA, and (4) Redwood-Prairie Creek PRA. EPA = extent population area.

The Redwood and Prairie Creek PRA (fig. 24) is the largest PRA (6.9 percent of the historical range in California). Sixty percent of the PRA is currently suitable habitat or high-value, low-elevation OGS habitat, and it also contains large tracts of young forest being actively managed to accelerate the restoration of old-growth forest characteristics. This PRA provides the most significant opportunity for southward expansion of the range in California (fig. 25).

Landscape Connectivity Areas

LCAs include large areas of forest habitat that (1) occur between or adjacent to any combination of EPAs and PRAs, (2) require straight line dispersal distances that average >10 km from the 10 nearest verifiable adult female locations, and (3) currently do not appear suitable for supporting successful dispersal or reproduction. The primary intent of an LCA is to improve functional habitat connectivity, allowing martens to recolonize currently suitable, but unoccupied, habitat and supporting the exchange of individuals between existing and reestablished populations into the future. Furthermore, connectivity may be enhanced over longer distances or where dispersal barriers are present by including areas suitable for supporting marten reproduction to increase the probability of successful dispersal and the frequency of dispersal attempts. Unfortunately, habitat requirements for successful dispersal are poorly understood at present. Areas presently regarded as unsuitable have a combination of low landscape habitat suitability value and low home range-scale OGS value; but such areas may be capable of becoming suitable in the future. The HMCG assumes that successful dispersal across LCAs will be a function of their habitat quality and distance between EPAs and potential PRAs. At the present time, available information is sufficient to identify only one LCA in California, although ideally new information will be available in the near future to identify LCA locations in Oregon.

LCAs will continue to be evaluated based on their current and future ability to support marten dispersal, their proximity to extant populations, and the potential for connectivity with future marten populations. The HMCG intends that the forthcoming Humboldt Marten Habitat Management Guide, in conjunction with connectivity modeling, will assist achievement of LCA objectives. The HMCG also anticipates that developing a specific connectivity improvement plan may be desirable for all recommended LCAs. The HMCG does not anticipate that the entire area of any LCA will be completely dedicated to meeting marten connectivity improvement goals.

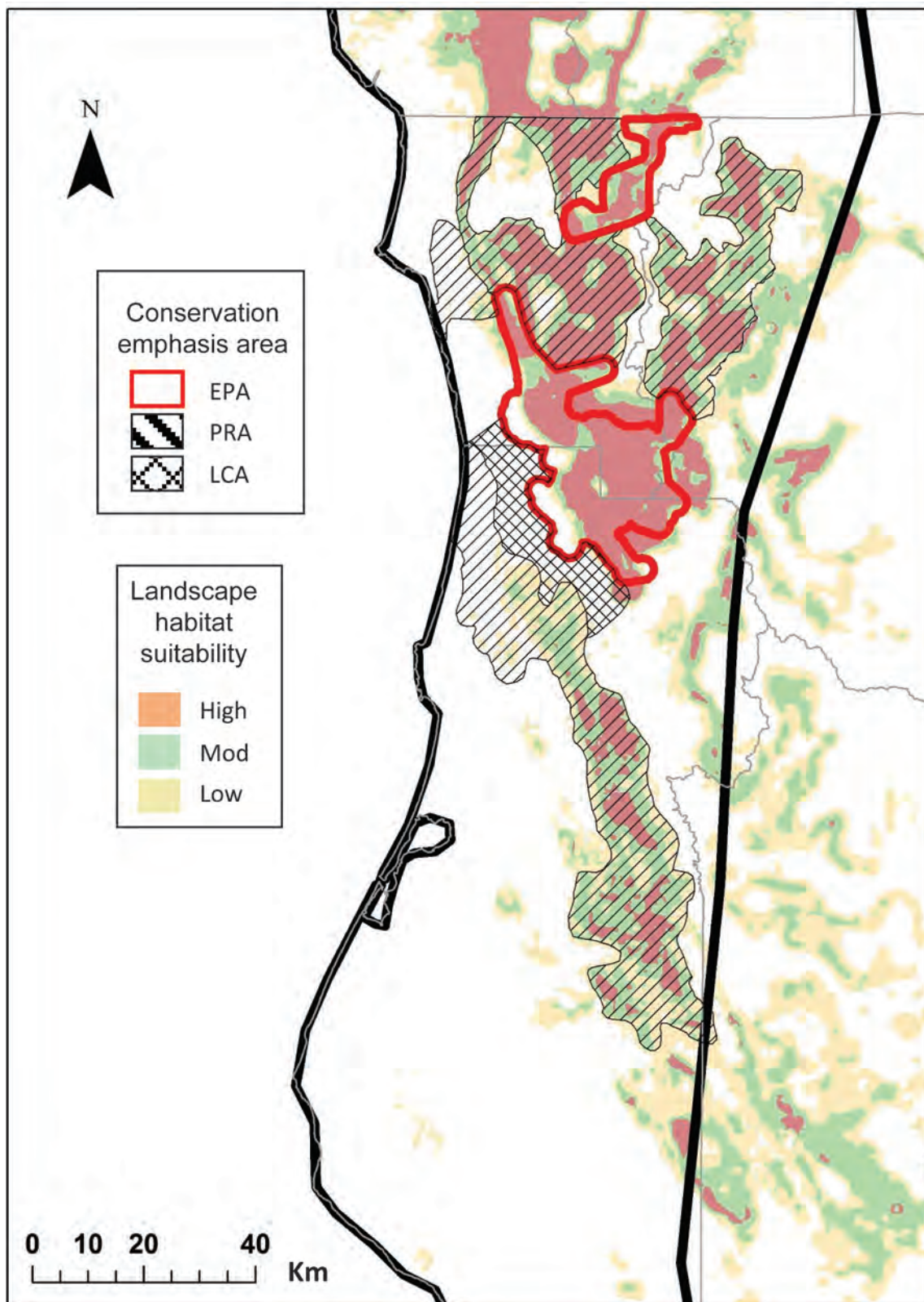


Figure 25—Location of the landscape connectivity area for the Humboldt marten (*Martes caurina humboldtensis*) in California. EPA = extent population area; PRA = population reestablishment area; LCA = landscape connectivity area.

Lower Klamath LCA—

The Lower Klamath LCA lies between the North Coastal California EPA to the northeast and the Redwood and Prairie Creek PRA to the west (fig. 25). Area statistics for this LCA are presented in table 1. The natural expansion of the marten population into the Redwood and Prairie Creek PRA and the maintenance of gene flow will likely require that the Lower Klamath LCA contain adequate suitable habitat for both successful dispersal and some level of residency, supporting both survival and reproduction. However, unassisted natural dispersal across this LCA appears unlikely unless areas of suitable habitat are maintained and enhanced owing to the presence of features (e.g., U.S. Highway 101, Klamath River) that will challenge successful dispersal. Although dispersal across this LCA may only require roughly 10 km straight-line distance movements, the Klamath River and U.S. Highway 101 likely represent filters with unknown levels of resistance for dispersing individuals. In addition, the amount of young regenerating forest present in this LCA will likely influence the numbers of marten predators and have an indirect influence on marten survival and successful dispersal. Thus, the degree to which the Redwood and Prairie Creek PRA will be isolated in the foreseeable future depends on both the maintenance and enhancement of habitat connectivity and the number of dispersers necessary to overcome the resistance to dispersal posed by the river and highway.

Potential Threats to the Humboldt Marten

In this section, the HMCG reviews and evaluates past, current, and future threats potentially affecting Humboldt marten populations or their habitat within the California portion of the assessment area. Potential threats are defined below. This assessment should not be construed as an attempt to assess threats under the federal Endangered Species Act for the purposes of determining whether a species should be listed as endangered or threatened. The purpose of this threats assessment is to evaluate potential threats in order to identify conservation actions that the HMCG and land managers within the assessment area can take to ameliorate these threats and help achieve the overall goal of this conservation strategy. Currently, the threats assessment has only been completed for the California portion of the assessment area, and the Oregon portion will be completed at a future date. This approach was similar to the conservation assessment processes by NatureServe (Master et al. 2012) and for two threat assessments for the West Coast Distinct Population Segment (DPS) of the fisher (Naney et al. 2012, USDI FWS 2014). To identify potential threats, the HMCG reviewed information in previous sections of this conservation assessment and relevant literature for other species and subspecies of martens in North America. Because of the similarity of natural history and the range overlap of

the fisher and Humboldt marten, we also relied on information from the two recent fisher threat assessments mentioned above.

The HMCG defined a potential threat as any activity or process that has caused, is causing, or may cause negative effects on marten populations resulting in:

- A further decline in populations.
- A further decline in the amount of suitable habitat.
- An impediment to restoration of marten populations or suitable habitat within the assessment area.

Once a threat is identified, it is evaluated to determine its potential impact to martens or existing and future suitable habitat conditions in EPAs, PRAs, and LCAs. Potential threats are evaluated with respect to both the scope (spatial extent) and severity (intensity) of their potential effects. Finally, threats are ranked according to the relative impact level (a combination of scope and severity classifications) to help prioritize threats that should be addressed by conservation actions and to help guide the use of limited resources for the greatest potential conservation returns.

Classification of Potential Threats

The HMCG identified 29 potential threats within four threat categories: (1) habitat loss and degradation, (2) climate change effects on habitat loss, (3) reduction in marten survival and reproduction, and (4) small and disjunct populations (table 2). For each potential threat the HMCG identified the timing, scope, severity, and impact for EPAs, and combined PRAs and LCAs in the California portion of the assessment area. The HMCG summarized the available scientific information for each threat regarding its potential direct (e.g., mortality) and indirect (e.g., habitat effects) population impacts (see the “Biophysical Environment,” “Human Modifications to the Environment,” and “Biological Information” chapters and app. 2 for summary information). When empirical evidence or other information was unavailable for a potential threat, we used expert opinion to estimate the scope, severity, and impact values. If significant information gaps resulted in significant levels of uncertainty in the scope and severity values for particular threats, information needed to fill these gaps was identified and listed in the “see Next Steps section on page 94.”

Timing—

Timing refers to whether the potential threat occurred primarily in the past (**historical**), is ongoing (**current**), or may occur in the short-term future (**future**). To provide a temporal extent for assessing most threats, the HMCG chose three marten generations, or 15 years. Marten generation time was calculated as follows: Female

Table 2—Timing, scope, and severity values for potential threats within the California portion of the assessment area^a

Potential threat	Timing	Scope- EPA^b	Severity- EPA	Scope- PRA^b and LCA^b	Severity- PRA and LCA
Habitat loss and degradation:					
Wildfire—					
Proportion of area affected by wildfire(s)	Ongoing	Large	Serious	Restricted	Serious
Emergency fire suppression	Ongoing	Restricted	Serious	Small	Serious
Postfire salvage logging	Ongoing	Restricted	Extreme	Small	Extreme
Lack of fire as a disturbance process	Ongoing	Small	Moderate	Small	Moderate
Forest management:					
Management of early-successional forests (≤60 years old)—					
Overstory removal (logging)	Ongoing	Small	Extreme	Small	Serious
Thinning (precommercial, commercial, restoration)	Ongoing	Restricted	Slight	Small	Slight
Shrub layer reduction	Ongoing	Restricted	Extreme	Small	Serious
Reduction of large residual structures (live trees, logs, snags)	Ongoing	Small	Serious	Small	Serious
Reduction of hardwoods	Ongoing	Small	Moderate	Small	Moderate
Management of mid-successional forests (60 to 120 years old)—					
Overstory removal (logging)	Ongoing	Small	Extreme	Small	Extreme
Thinning (commercial, restoration)	Ongoing	Small	Serious	Small	Moderate
Shrub layer reduction	Ongoing	Small	Extreme	Small	Serious
Reduction of large structures (live trees, logs, snags)	Ongoing	Small	Extreme	Small	Serious
Reduction of hardwoods	Ongoing	Small	Moderate	Small	Moderate
Removal of late-successional forest (>120 to 150 years old)	Ongoing	Small	Extreme	Small	Extreme
Human development (urbanization, road construction, recreation, agriculture, large reservoirs)	Ongoing	Small	Extreme	Small	Extreme
Cumulative effects of habitat loss and degradation leading to large-scale fragmentation of suitable habitat	Ongoing	Pervasive	Serious	Large	Serious
Climate change effects on habitat loss—					
Climate change: mid-21st century (2040–2060)	Short term	Large	Slight	Large	Moderate
Climate change: late 21st century (2080–2100)	Long term	Pervasive	Moderate	Pervasive	Serious
Reduction in marten survival and reproduction—					
Legal trapping ^c and incidental capture during legal trapping	Ongoing	Small	Moderate	Small	Moderate
Research activities (live-trapping, radio-collaring)	Ongoing	Small	Slight	Small	Slight

Table 2—Timing, scope, and severity values for potential threats within the California portion of the assessment area^a (continued)

Potential threat	Timing	Scope- EPA^b	Severity- EPA	Scope- PRA^b and LCA^b		Severity- PRA and LCA
				PRA^b	LCA^b	
Collision with vehicles	Ongoing	Small	Extreme	Small	Small	Extreme
Exposure to toxicants (primarily rodenticides from illegal marijuana grows)	Ongoing	Restricted	Serious	Restricted	Restricted	Serious
Lethal diseases	Ongoing	Serious	Restricted	Restricted	Restricted	Serious
Human-influenced predation (habitat modification favoring marten predators)	Ongoing	Large	Extreme	Moderate	Moderate	Extreme
Small and disjunct population threats-						
Inbreeding depression	Future	Large	Moderate	NA	NA	NA
Demographic stochasticity (environmental variation that affects survival and reproduction)	Future	Restricted	Moderate	NA	NA	NA

^a When information to make an accurate estimate of the scope or severity of a particular threat was lacking, values were estimated using expert opinion. For details on the rationale for each potential threat's classification, see appendix 2. Forest age class-seral stage breaks were based on age-seral relationships from Jimerson et al. (1996) and Sawyer et al. (2000b)

^b EPA = extant population area; PRA = population re-establishment area; LCA = landscape connectivity area.

^c For California, legal trapping refers to the legal trapping for other species using traps that may also capture martens, and trapping on tribal lands that may include martens or use of traps capable of capturing martens.

martens typically first give birth to young at 2 years of age (Mead 1994). Buskirk et al. (2012) reviewed published studies on marten survival across North America and estimated that adult (>2 years old) annual survival was 0.75 for all adult ages. Using these numbers for age at first reproduction (α) and adult survival (s), marten generation time (T) is calculated as $T = \alpha + [s/(1-s)]$ or $T = 2 + [0.75/(1-0.75)] = 2 + 3$. Thus marten generation time (T) = 5 years, and three generations equals 15 years. For assessing potential threats related to climate change, we selected two temporal extents, mid-21st century (2040–2060) and late 21st century (2080–2100), to match the temporal extents of existing climate model predictions.

Scope—

The scope of a potential threat refers to the estimated proportion of each EPA or the combined PRAs and LCAs that reasonably can be expected to be affected by a potential threat within 15 years (except for the future potential threats of climate change, which is evaluated at longer time frames, as noted above). Scope categories include:

- Pervasive:** 71 to 100 percent—affects all or most of the suitable habitat or individuals.
- Large:** 31 to 70 percent—affects much of the suitable habitat or individuals.
- Restricted:** 11 to 30 percent—affects some of the suitable habitat or individuals.
- Small:** 1 to 10 percent—affects a small proportion of the suitable habitat or individuals.

Severity—

The severity of a potential threat is the estimated level of impact to habitat or individual martens that reasonably can be expected from the potential threat within 15 years (except for potential threats of climate change at longer timeframes, as noted above). Importantly, severity **is nested within** the scope of the potential threat, such that if the scope estimation is that a potential threat may have an impact on 11 to 30 percent of the suitable habitat or individuals, severity describes the degree of impact that may occur to the 11 to 30 percent of suitable habitat or individuals. Severity is estimated by the degree of decline it may cause to martens or their habitat using the following categories:

- Extreme:** 71 to 100 percent—likely to have an impact on all or most of the suitable habitat or individuals within the scope defined.
- Serious:** 31 to 70 percent—likely to have an impact on much of the suitable habitat or individuals within the scope defined.

Moderate: 11 to 30 percent—likely to have an impact on some of the suitable habitat or individuals within the scope defined.

Slight: 1 to 10 percent—likely to have an impact on a small proportion of the suitable habitat or individuals within the scope defined.

Both the scope and severity classifications incorporate uncertainty by designating a range within each category that best fits the current knowledge base for each potential threat. The specific rationale and supporting information for assigning scope and severity classifications for each potential threat are included in appendix 2.

Here is an example of scope and severity estimation: within the Wildfire potential threat category for the California EPAs (table 2; app. 2), to evaluate the scope (“proportion of area affected by wildfire[s]”), we examined the size of recent (i.e., from 2000 to 2014, the past 15 years) wildfires within the vicinity of the EPAs and determined that a single large wildfire could realistically affect 31 to 70 percent (thus, scope = “large”) of the suitable Humboldt marten habitat within the California EPAs over the next 15 years. For the severity estimate, the HMCG determined that even a low-severity burn (most large wildfires contain areas with high and low burn severity) would likely cause a short-term loss or degradation of suitable habitat by removing the extensive shrub layer typically required by the Humboldt marten. The HMCG estimated that within the scope of the suitable habitat in the California EPAs that could be affected by wildfire over the next 15 years, 31 to 70 percent (severity = “serious”) of that suitable habitat could be lost or degraded, because wildfires of any severity could result in habitat loss or degradation.

In another example, within the “reduction in marten survival and reproduction” potential threat category, to evaluate the scope for the “collision with vehicles” subcategory we presumed that greater vehicle frequency and speed would increase the probability of a vehicle striking a marten. But the HMCG determined that only small portions (1 to 10 percent, thus scope = “small”) of the California EPAs, PRAs, and LCAs contained highways with relatively heavy traffic traveling at relatively high speed (i.e., ≥ 45 mph [72 kph]). For the severity estimate, the HMCG presumed that all martens struck by a vehicle would sustain mortal injuries, so we estimated that within the limits of the scope, 71 to 100 percent (severity = “extreme”) of all martens struck by a vehicle would be killed.

Degree of Potential Threat Impacts

The HMCG calculated the impact level for each potential threat by combining the scope and severity scores from table 2 into a calculation matrix (table 3) per Salafsky et al. (2008). The combinations of the scope and severity classification ranges defined the threat impact level. Timing was not applied in the calculation of the

Table 3—Calculation matrix for potential threat impact level

Severity	Scope			
	Pervasive (71–100 percent)	Large (31–70 percent)	Restricted (11–30 percent)	Small (≤10 percent)
Extreme: (71 to 100 percent)	Very high	High	Medium	Low
Serious: (31 to 70 percent)	High	High	Medium	Low
Moderate: (11 to 30 percent)	Medium	Medium	Low	Low
Slight: (≤10 percent)	Low	Low	Low	Low

threats impact level, but was included in the summary assessment. Of the 11 threats evaluated, none were rated as “very high” impact, three were rated as “high,” and the remainder were rated as “medium” or “low” (table 4). The three potential threats with the highest impact values were large-scale fragmentation from cumulative effects from past timber harvest, wildfire, and lethal disease. Threats with medium or high-impact levels were ranked according to the overall impact of the category (table 5).

Conservation Actions

For each potential threat, the HMCg identified the conservation actions that may reduce or eliminate the potential impacts (table 5). Potential threats were ranked according to their impact level from highest to lowest.

Integration of Conservation Actions and Conservation Emphasis Areas

The conservation emphasis area categories (EPA, PRA, and LCA) identify specific areas where protection of existing suitable habitat, restoration of suitable habitat conditions, or reduction of potential threats are designed to promote marten persistence and facilitate the increase in population size and distribution. Conservation actions were designed to ameliorate threats; however, their impacts will not be equal in all conservation emphasis areas.

High-Priority Conservation Actions

Table 5 lists conservation actions that address impacts of all threats with moderate to high impact levels. However, these actions may not be applicable in all settings,

The three potential threats with the highest impact values were large-scale fragmentation from cumulative effects of past timber harvest, wildfire, and lethal disease.

Table 4—Impact levels for all threat categories evaluated

Impact level	Number of threat categories	Threat categories included
Very high	0	None
High	3	– Large-scale fragmentation from cumulative effects of past timber harvest and severe wildfire – Wildfire – Lethal disease
Medium	8	– Shrub layer reduction – Fire suppression – Postfire salvage – Exposure to toxicants – Human-influenced predation – Climate change: late 21st century – Climate change: mid-21st century – Inbreeding depression
Low	18	– Loss of late-successional forest – Lack of fire as a disturbance process – Overstory removal: early and mid-successional – Thinning: early and mid-successional – Reduction of large residual structures: early and mid-successional – Reduction of hardwoods: early and mid-successional – Legal trapping and incidental capture – Collision with vehicles – Demographic stochasticity

Table 5—Threats impact level, threat rank, and conservation actions for potential threats evaluated for California

Threat rank	Threat description	EPAs				PRAs/LCA			
		Impact	Timing	Impact	Timing	Impact	Timing	Impact	Possible conservation actions
1	Habitat loss and degradation:								
1	Cumulative effects of habitat loss and degradation leading to large-scale fragmentation of suitable habitat	High	Past and ongoing	High	Past and ongoing				As appropriate, federal, state, tribal, and private land managers could consider the spatial categories of extant population areas, population reestablishment areas, and connectivity improvement areas in project planning, and where appropriate integrate them into long-term land management plans. Within these spatial categories, management ensure that currently suitable habitat is protected or enhanced and strategic areas of habitat not currently suitable are managed to enhance their suitability as soon as possible. Conduct population monitoring to measure the effectiveness of these activities to inform adaptive management.
1	Proportion of area affected by wildfire(s)	High	Ongoing	Medium	Ongoing				As appropriate, federal, state, tribal, and private land managers could develop fire-response priorities for occupied marten habitat areas and develop fuels reduction prescriptions that reduce the risk of wildfire while maintaining the structural elements required by the Humboldt marten. They could increase the distribution and number of populations to reduce the potential for wildfire to significantly affect population persistence.
1	Shrub layer reduction	Medium	Ongoing	Low	Ongoing				As appropriate, federal, state, tribal, and private land managers could develop timber harvest, thinning, fuels reduction, reforestation, and prescribed fire methods that minimize impacts to ericaceous-dominated shrub layers where possible to maintain suitability for the marten. Identify stand management alternatives that could restore or enhance dense ericaceous-dominated shrub cover where it has been lost or significantly reduced.

Table 5—Threats impact level, threat rank, and conservation actions for potential threats evaluated for California^a (continued)

Threat rank	Threat description	EPAs				PRAs/LCA		Possible conservation actions
		Impact	Timing	Impact	Timing	Impact	Timing	
1	Emergency fire suppression	Medium	Ongoing	Low	Ongoing			Federal, state, tribal, and private land staff could provide detailed maps of important marten habitat areas to incident control teams, to enable consideration of protecting critical areas in strategic fire suppression planning. Maintain large snags and logs during emergency fire suppression in late-successional coniferous habitat to the greatest extent possible. Reduce wildfire severity through fuels reduction projects and prescribed burning to maintain large trees and logs postfire.
1	Postfire salvage logging	Medium	Ongoing	Low	Ongoing			Federal, state, tribal, and private land managers could minimize the removal of structural elements important for suitable marten habitat including live and standing dead trees of large diameter.
2	Reduction in marten survival and reproduction:							
2	Lethal diseases	High	Ongoing	Medium	Ongoing			Managers could do the following: inoculation of martens captured during research activities against lethal diseases such as CDV and rabies, monitor disease prevalence and outcomes to determine exact scope and severity of this threat to marten populations. Increase the distribution and number of populations to reduce the probability of disease to threaten population persistence, establish field research protocols to reduce the transmission of lethal pathogens between martens and other species.
2	Exposure to toxicants (primarily rodenticides from marijuana cultivation sites)	Medium	Ongoing	Medium	Ongoing			Conduct aerial surveys to detect and remove active grow sites in critical marten habitat. Test all dead martens for exposure to toxicants and apply new methods, when they are developed, for testing live animals for these compounds.

Table 5—Threats impact level, threat rank, and conservation actions for potential threats evaluated for California (continued)

Threat rank	Threat description	EPAs		PRAs/LCA		Possible conservation actions
		Impact	Timing	Impact	Timing	
2	Human-influenced predation	Medium	Ongoing	Medium	Ongoing	Identify how land management activities can influence predation rates on martens by (1) affecting the distribution and abundance of marten predators, and (2) increasing the likelihood of predation when encounters are enabled by habitat degradation. Develop and suggest management measures in the Habitat Management Guide that can reduce both the abundance of marten predators and their risk of predation. Evaluate the potential efficacy of short-term removal of marten predators until more favorable habitat conditions are restored.
3	Climate change effects on habitat loss:					
3	Climate change: mid-21 st century (2040–2060)	Low	Future	Medium	Future	Establish marten populations closer to the coast to reduce the potential impacts from climate change on inland habitat. Enhance connectivity from interior to coastal areas of current habitat suitability. Coordinate with federal, state, tribal, and private land managers to integrate the conservation emphasis areas: extant population areas, population reestablishment areas, and landscape connectivity areas into their land management plans.
3	Climate change: late 21 st century (2080–2100)	Medium	Future	High	Future	Same as previous.
4	Small and disjunct population effects:					
4	Inbreeding depression	Medium	Ongoing	NA	NA	Determine the extent of loss of genetic diversity in extant populations. If loss is significant, develop plans for translocation of individuals from extant population areas to enhance genetic diversity.

NA= not applicable.

and may be modified to achieve desired outcomes for martens. The HMCG recognizes that project areas often have unique circumstances and environmental conditions; therefore, design and evaluation of management actions will likely be best accomplished on a case-by-case basis.

Here the HMCG identifies specific conservation actions that could mitigate the threats with the highest impact levels.

California—

- **Strategic habitat management and restoration:** Four (40 percent) of the threats with the greatest impacts on the Humboldt marten (existing large-scale fragmentation, wildfire, shrub layer reduction, and human-influenced predation) could be addressed through the maintenance and restoration of suitable habitat. Maintenance of suitable habitat is most important where it exists in EPAs, PRAs, and LCAs. Restoration of suitable habitat is most needed to counteract the large-scale fragmentation of suitable habitat from past actions. Restoration would increase the overall amount, patch sizes, and connectivity of suitable habitat across all conservation emphasis areas. Young stands can take several decades to grow beyond the stages that support key marten predators and to then develop suitable characteristics for marten use. Thus, conservation actions that would speed attainment of better stand conditions in key areas are high-priority conservation actions.
- **Evaluation of population re-establishment through assisted dispersal:** Three (30 percent) of the threats with the greatest impacts on the Humboldt marten (existing large-scale fragmentation, wildfire, and lethal disease) could be addressed by increasing the distribution and number of marten populations. Even if initiated promptly, habitat management actions may take decades to produce conditions supporting functional connectivity and colonization of presently unoccupied areas. Therefore, the HMCG recommends immediate evaluation of the feasibility of translocation of individuals to unoccupied suitable areas in PRAs. Obviously, identification of donor areas for translocation must consider impacts to extant populations. However, if areas can be identified that are presently acting as population sinks, where individuals disperse but contribute little to population growth or persistence, these areas have the potential for the removal of individuals with minimal impacts to donor populations.

- **Monitor populations to detect:** (1) changes in distributions and abundance over time, (2) responses to restoration and management actions, (3) responses to natural disturbances (e.g., wildfire) and disease outbreaks. This conservation action could improve the understanding of the scope and severity of threats and provide timely information on the results of restoration and management actions.

Oregon—

Additional information is needed to identify specific conservation actions that could address threats to martens in the Oregon portion of the assessment area; thus, the HMCG is not listing any options at this time. In the interim, parties interested in proactive management can look to the recommendations for the California portion of the assessment area. Many of the important habitat management and restoration needs for Humboldt martens will likely be applicable rangewide.

Next Steps and Key Information Needs for Further Development of the Conservation Strategy

Throughout the strategy development process, the HMCG identified key information gaps and tools necessary for evaluation and implementation of conservation actions as well as the development of future conservation strategy modules. These include the following (not in order of importance):

Steps for inventorying, monitoring, and managing populations—

- Determine and monitor the abundance and distribution of martens in each EPA to provide baseline information and trends through time. Determine the number and distribution of martens in the California-Oregon Border EPA, Prairie Creek Redwoods State Park, and both Oregon EPAs. Conduct surveys in the largest areas of suitable habitat in all PRAs around EPAs to identify any additional areas that support martens. Use survey methods capable of detecting trends in distribution and abundance and of evaluating the effects of natural disturbance events and management and conservation actions over time. Include survey design considerations for a survey protocol suitable for long-term monitoring of multiple forest carnivore species' distribution and population status.
- In Oregon, develop approaches to assess the effects of legal trapping, roadkill mortality, and other anthropogenic sources of mortality on marten population size, growth rate, and distribution. Develop and distribute a protocol and collection forms for salvaging marten roadkill in Oregon

and California. Identify and implement measures to reduce anthropogenic mortality sources: (1) evaluate and implement alternative measures for improving the permeability of U.S. Highway 101, and other highways with the potential to impact martens, to successful marten crossings in areas of Oregon and California where it overlaps populations currently or areas where population expansion is planned, (2) close legal trapping season for Humboldt martens or restrict trapping for other species in the occupied marten range where martens may be captured as “bycatch” until population sizes are large enough to sustain mortality from trapping, and (3) evaluate risk-reward for new research projects that use capture methods that may result in marten mortalities and encourage use of noninvasive methods when possible.

- Determine scale and magnitude of impacts from legal and illegal rodenticides used in both control of mountain beavers (*Aplodontia rufa*) and marijuana cultivation. If necessary, develop regulatory approaches to address this mortality factor. Encourage the development of methods to assay toxicant levels in live animals.
- Determine whether extant populations have lost significant genetic diversity or are at risk for inbreeding that could lead to reduced fitness.
- Determine the short- and long-term responses of marten distribution and demographics, important marten prey, and marten predators to wildfire, including the effects of variation in the spatial pattern and intensity of wildfire.
- Develop predictive tools to assess impacts of wildfire on marten habitat to model future fire scenarios and provide decision support for fire management planning. Identify management actions that could alleviate negative short- or long-term effects to habitat.

Steps for evaluating scale-specific habitat suitability, predicting habitat responses to management actions and natural disturbance—

- Determine home range size and the habitat composition and patch size characteristics that most influence marten occupancy, survival, and reproduction at the home range scale across the three main habitat types they occupy.
- Develop a Humboldt marten habitat management guide capable of identifying the habitat characteristics most important for supporting marten occupancy, reproduction, and survival at the stand and home range scale. Design this guide to help managers identify alternative actions most likely

to support the maintenance or improvement of suitable habitat conditions for martens.

- Conduct experimental studies to monitor short- and long-term effects of alternative silvicultural and fuels management approaches on important marten habitat structures and on key prey and predators. Identify the habitat conditions capable of supporting functional connectivity. Develop models to identify the specific areas most likely to support marten movement, dispersal, and occupancy between EPAs and PRAs. Develop specific management approaches to enhance habitat conditions where movement is predicted to occur between EPAs and PRAs.
- Expand knowledge of the prey and habitat relationships of key marten predators, such as the bobcat. Determine the distributional response of key marten predators to various forest management practices at the landscape scale in the California and Oregon EPAs. Determine the diet and relationship to specific forest management methods for key marten predators. Identify stand- and landscape-scale management alternatives to reduce the abundance and distribution of key marten predators, such as the bobcat, where important.
- Evaluate the accuracy of the marten landscape habitat suitability model outside the initial development area and make revisions as necessary, using recently collected detection data to better inform the model. Use recent survey data from the shore pine and shore pine transitional forests to improve the model's performance in this habitat type. Determine the appropriate application of the model and predictions based on its use. Evaluate the efficacy of modeling important marten predator distribution for improving the model's accuracy rangewide.
- Determine within-stand characteristics that influence marten selection for foraging, resting, and denning. Identify stand management approaches capable of maintaining key marten habitat elements for these behaviors. Develop consistent methods of vegetation sampling to help facilitate the comparison of results across sites and studies.
- Determine short- and long-term population responses of martens, important marten prey, and marten predators to different spatial patterns and intensities of wildfire. Identify management actions that could alleviate negative short- or long-term effects to habitat.

- Determine marten dispersal characteristics, including distance, timing, and factors contributing to successful dispersal. Determine the characteristics of functional connectivity capable of supporting successful marten dispersal, and identify management alternatives capable of maintaining and improving dispersal where necessary.

Steps for evaluating and implementing methods for population re-establishment—

- Conduct a feasibility assessment for each PRA to determine (1) amount of reproductive habitat available, (2) amount of suitable habitat available, (3) prey resources available, (4) risk of predation, (5) potential distribution and carrying capacity, and (6) high-priority areas for restoration or improvement of suitable habitat conditions.
- Evaluate the desirability and feasibility of assisted dispersal for martens from the North Coastal California EPA. If assisted dispersal is feasible, develop an implementation plan that includes identification of regulatory, planning, and funding steps necessary for implementation.
- Determine the conditions under which captive breeding may be necessary. Identify quantifiable measures for when populations may qualify for this option and identify a schedule of actions needed to initialize this action.

Acknowledgments

This conservation assessment and strategy would not have been possible without the hard work and contributions of the members of the Humboldt Marten Conservation Group. Prominent among those was Dr. Lowell V. Diller, who passed away on March 4, 2017. As a member of the Conservation Group, Lowell made significant contributions through his knowledge of wildlife ecology and forest management, as well as his creative thinking, optimism, and old-fashioned common sense.

U.S. Equivalents

When you know:	Multiply by:	To get:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Kilometers (km)	0.621	Miles
Hectares (ha)	2.47	Acres
Degrees Celsius (°C)	$1.8\text{ }^{\circ}\text{C} + 32$	Degrees Fahrenheit

References

- Agee, J.K. 1993.** Fire ecology of Pacific Northwest forests. Covelo, CA: Island Press. 505 p.
- Allouche, O.; Tsoar, A.; Kadmon, R. 2006.** Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology*. 43(6): 1223–1232.
- Anderson, M.K. 2006.** The use of fire by Native Americans in California. In: Sugihara, N.; van Wagendonk, J.; Shaffer, K.; Fites-Kaufmann, J.; Thode, A., eds. *Fire in California's ecosystems*. Berkeley, CA: University of California Press: 417–430.
- 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.
- Anonymous. 1914.** Report of fur-bearing animals. *The Oregon Sportsman*. 2: 20.
- Aubry, K.; Wisely, S.; Raley, C.; Buskirk, S.W. 2004.** Zoogeography, spacing patterns, and dispersal in fishers: insights gained from combining field and genetic data. In: Harrison, D.; Fuller, A.; Proulx, G., eds. *Martens and fishers in human-altered environments: an international perspective*. New York: Springer Science: 201–222. Chapter 10.
- Bernard, S.L.; Gorham, J.R.; Ryland, L.M. 1984.** Biology and diseases of ferrets. In: Fox, J.G.; Cohen, B.J.; Loew, F.M., eds. *Laboratory animal medicine*. New York: Academic Press: 385–397.
- 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. 26 p.
- Bowler, D.E.; Benton, T.G. 2005.** Causes and consequences of animal dispersal strategies: relating individual behavior to spatial dynamics. *Biological Reviews*. 80: 205–225.
- Broquet, T.; Johnson, C.A.; Petit, E. [et al.]. 2006.** Dispersal and genetic structure in the American marten, *Martes americana*. *Molecular Ecology*. 15: 1689–1697.
- Brown, R.N.; Gabriel, M.W.; Wengert, G.M. [et al.]. 2008.** Pathogens associated with fishers. In: *Pathogens associated with fishers (Martes pennanti) and sympatric mesocarnivores in California: final draft report to the U.S. Fish and Wildlife Service for Grant #813335G021*. Yreka, CA: U.S. Department of the Interior, Fish and Wildlife Service: 3–47.

- 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.
- Buskirk, S.W.; Bowman, J.; Gilbert, J.H. 2012.** Population biology and matrix demographic modeling of American martens and fishers. In: Aubry, K.B.; Zielinski, W.J.; Raphael, M.G. [et al.], eds. *Biology and conservation of martens, sables, and fishers: a new synthesis*. Ithaca, NY: Cornell University Press: 77–92.
- Buskirk, S.W.; Powell, R.A. 1994.** Habitat ecology of fishers and American martens. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A., eds. *Martens, sables, and fishers: biology and conservation*. Ithaca, NY: Cornell University Press: 283–296.
- Buskirk, S.W.; Ruggiero, L.R. 1994.** American marten. In: Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W. [et al.], eds. *American marten, fisher, lynx, and wolverine in the western United States*. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 7–37.
- 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.
- Carey, A.B. 1995.** Sciurids in Pacific Northwest managed and old-growth forests. *Ecological Applications*. 5: 648–661.
- Carey, A.B.; Johnson, M.L. 1995.** Small mammals in managed, naturally young, and old-growth forests. *Ecological Applications*. 5: 336–352.
- Center for Biological Diversity [CBD]. 2010.** Petition to list the Humboldt marten (*Martes americana humboldtensis*) as threatened or endangered under the federal Endangered Species Act. Flagstaff, Arizona, Center for Biological Diversity. Submitted to: U.S. Department of the Interior on (28 September, 2010). 47 p.
- 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.

- Chappell, C.B.; Crawford, R.C.; Barrett, C. [et al.]. 2001.** Wildlife habitats: descriptions, status, trends, and system dynamics. In: Johnson, D.H.; O'Neil, T.A., eds. Wildlife-habitat relationships of Oregon and Washington. Corvallis, OR: Oregon State University Press: 22–114.
- Chappell, C.B.; Kagan, J. 2001.** Westside grasslands. In: Johnson, D.H.; O'Neil, T.A., eds. Wildlife-habitat relationships of Oregon and Washington. Corvallis, OR: Oregon State University Press: 41–43.
- Clark, T.W.; Anderson, E.; Douglas, C.; Strickland, M. 1987.** *Martes americana*. Mammalian Species. 289: 1–8.
- Clark, T.W.; Campbell, T.M. 1976.** Population organization and regulatory mechanisms of pine martens in Grand Teton National Park, Wyoming. In: Linn, R.M., ed. Proceedings of the first conference on scientific research in national parks. New Orleans, LA: 293–295.
- Cushman, S.A.; Raphael, M.G.; Ruggiero, L.F. [et al.]. 2011.** Limiting factors and landscape connectivity: the American marten in the Rocky Mountains. *Landscape Ecology*. 26(8): 1137.
- Dawson, N.G. 2008.** Vista Nortena: tracking historical diversification and contemporary structure in high latitude mesocarnivores. Albuquerque, NM: University of New Mexico. 178 p. Ph.D. dissertation.
- Dawson, N.G.; Cook, J.A. 2012.** Behind the genes: diversification of North American martens (*Martes americana* and *M. caurina*). In: Aubry, K.B.; Zielinski, W.J.; Raphael, M.G. [et al.], eds. Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press: 23–38.
- Delheimer, M.S.; Moriarty, K.M.; Slauson, K.M.; Roddy, A.M.; Early, D.A., Hamm, K.A. [N.d.].** Comparative reproductive ecology of two subspecies of Pacific martens (*Martes caurina*) in coastal and montane forests of California. Northwest Science. Manuscript in preparation. On file with: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3625 93rd Avenue, Olympia, WA 98512. Deem, S.L.; Spelman, L.H.; Yates, R.A.; Montali, R.J. 2000. Canine distemper in terrestrial carnivores: a review. *Journal of Zoo and Wildlife Medicine*. 31(4): 441–451.
- DellaSala, D.A. 2013.** Rapid assessment of the Yale framework and adaptation blueprint for the North America Pacific coastal rainforest. Data Basin. <http://databasin.org/articles/172d089c062b4fb686cf18565df7dc57>. (27 August 2014).

- DellaSala, D.A.; Moola, F.; Alaback, P. [et al.]. 2011.** Temperate and boreal rainforests of the Pacific coast of North America. In: DellaSala, D.A., ed. Temperate and boreal rainforests of the world: ecology and conservation. Washington, DC: Island Press: 42–81.
- Dillon, L. 1961.** Historical subspeciation in the North American marten. *Systematic Zoology*. 10: 49–64.
- Dillon, R. 1975.** Siskiyou Trail: the Hudson's Bay Company route to California. San Francisco, CA: McGraw-Hill Co: 458 p.
- Dixon, J. 1925.** A closed season needed for fisher, marten, and wolverine. *California Fish and Game*. 11: 23–25.
- Donadio, E.; Buskirk, S.W. 2006.** Diet, morphology, and interspecific killing in *Carnivora*. *American Naturalist*. 167: 524–536.
- 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. 49 p. M.S. thesis.
- Environmental Protection Information Center; Center for Biological Diversity [EPIC and CBD]. 2015.** Petition to the California Fish and Game Commission to list the Humboldt marten (*Martes caurina humboldtensis*) as an endangered species under the California Endangered Species Act. Arcata, CA. 38 p.
- Fecske, D.M.; Jenks, J.A. 2002.** Dispersal by a male American marten, *Martes americana*. *The Canadian Field Naturalist*. 116: 309–311.
- Fortin, C.; Cantin, M. 2004.** Harvest status, reproduction and mortality in a population of American martens in Quebec, Canada. In: Harrison, D.J.; Fuller, A.K.; Proulx, G., eds. Martens and fishers (*Martes*) in human-altered environments: an international perspective. New York, Springer: 221–234.
- Fox, L. 1996.** Current status and distribution of coast redwood. In: LeBlanc, J., ed. Coast redwood forest ecology and management. Berkeley, CA: University of California: 18–19.
- Franklin, J.; Miller, J.A. 2010.** Mapping species distributions: spatial inference and prediction. Cambridge, United Kingdom: Cambridge University Press: 320 p.
- 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.B.; Zielinski, W.J.; Raphael, M.G. [et al.], 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. [et al.]. 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: 1–15.
- Gabriel, M.W.; Woods, L.W.; Wengert, G.M. [et al.]. 2015.** Patterns of natural and human-caused mortality factors of a rare forest carnivore, the fisher (*Pekania pennanti*) in California. *PloS one*. 10(11): e0140640. doi:10.1371/journal.pone.0140640: 1–19.
- Gibilisco, C.J. 1994.** Distributional dynamics of modern *Martes* in North America. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A., eds. *Martens, sables, and fishers: biology and conservation*. Ithaca, NY: Cornell University Press: 59–71.
- Gilbert, J.H.; Wright, J.L.; Lauten, D.J.; Probst, J.R. 1997.** Den and rest-site characteristics of American marten and fisher in northern Wisconsin. In: Proulx, G.; Bryant, H.N.; Woodard, P.M., eds. *Martes: taxonomy, ecology, techniques, and management*. Edmonton, AB, Canada: Provincial Museum of Alberta: 135–145.
- Godbout, G.; Ouellet, J-P. 2008.** Habitat selection of American marten in a logged landscape at the southern fringe of the boreal forest. *Ecoscience*. 15(3): 332–342.
- Graham, R.W.; Graham, M.A. 1994.** Late Quaternary distribution of *Martes* in North America. In: Buskirk, S.; Harestad, A.; Raphael, M.G.; Powell, R.A., eds. *Martens, sables and fishers: biology and conservation*. Ithaca, NY: Cornell University Press: 26–58.
- Grinnell, J.; Dixon, J.S. 1926.** Two new races of the pine marten from the Pacific Coast of North America. *Zoology*. 21: 411–417.
- Grinnell, J.; Dixon, J.S.; Linsdale, J.M. 1937.** *Fur-bearing mammals of California: their natural history, systematic status, and relations to man*. Berkeley, CA: University of California Press: 375 p. Vol. 1.

- Hagar, J.C. 2003.** Functional relationships among songbirds, arthropods, and understory vegetation in Douglas-fir forests, western Oregon. Corvallis, OR: Oregon State University. 143 p. Ph.D. dissertation.
- Hagmeier, E. 1958.** Inapplicability of the subspecies concept to North American marten. *Systematics and Zoology*. 7: 1–7.
- Hall, E.R. 1981.** *Martes americana*. The mammals of North America. 2nd ed. New York: John Wiley & Sons: 980–985. Vol. 2.
- Hamm, K.A.; Diller, L.V. 2009.** Forest management effects on abundance of woodrats in northern California. *Northwestern Naturalist*. 90(2): 97–106.
- Hamm, K.A.; Diller, L.V.; Lamphear, D.W.; Early, D.A. 2012.** Ecology and management of *Martes* on private timberlands in north coastal California. In: Standiford, R.B.; Weller, T.J.; Piirto, D.D.; Stuart, J.D., eds. Proceedings of the coast redwood forests in a changing California: a symposium for scientists and managers. Gen. Tech. Rep. PSW-GTR-238. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 419–425.
- Hansen, E.M.; Goheen, D.J.; Jules, E.S.; Ullian, B. 2000.** Managing Port Orford-cedar and the introduced pathogen *Phytophthora lateralis*. *Plant Disease*. 84(1): 4–14.
- Harcombe, P.A.; Greene, S.E.; Kramer, M.G. [et al.]. 2004.** The influence of fire and windthrow dynamics on a coastal spruce-hemlock forest in Oregon, USA, based on aerial photographs spanning 40 years. *Forest Ecology and Management*. 194: 71–82.
- 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.
- Harrison, S.; Rajakaruna, N. 2011.** Serpentine: the evolution and ecology of a model system. Berkeley, CA: University of California Press: 464 p.
- 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.
- Hayes, J.P.; Horvath, E.G.; Hounihan, P. 1995.** Townsend's chipmunk populations in Douglas-fir plantations and mature forests in the Oregon Coast Range. *Canadian Journal of Zoology*. 73: 67–73.

- Haynes, R.W. 2001.** Overview. In: Haynes, R.W.; Perez, G.E., tech. eds. Northwest Forest Plan research and synthesis. Gen. Tech. Rep. PNW-GTR-498. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 2–9.
- Hewitt, G. 1996.** Some genetic consequences of ice ages, and their role in divergence and speciation. *Biological Journal of the Linnean Society*. 58: 247–276.
- Higley, E.M. 2008.** Personal communication. Wildlife biologist, Hoopa Valley Tribal Forestry, P.O. Box 368, Hoopa, CA 95546.
- Hodgman, T.P.; Harrison, D.J.; Phillips, D.M.; Elowe, K.D. 1997.** Survival of American marten in an untrapped forest preserve in Maine. In: Proulx, G.; Bryant, H.N.; Woodard, P.M., eds. *Martes: taxonomy, ecology, techniques, and management*. Edmonton, AB, Canada: Provincial Museum of Alberta: 86–99.
- Impara, P.C. 1997.** Spatial and temporal patterns of fire in the forests of the central Oregon Coast Range. Corvallis, OR: Oregon State University. 354 p. Ph.D. dissertation.
- Jacobs, M. 1934.** Coos and Upper Coquille ethnological notes, 1931–1934. Seattle, WA: Archives of the University of Washington: Notebook. 128: 42.
- Jimerson, T.M.; Hoover, L.D.; McGee, E.A. [et al.]. 1995.** A field guide to serpentine plant associations and sensitive plants in northwestern California. R5-ECOL-TP-006. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 347 p.
- Jimerson, T.M.; McGee, E.A.; Jones, D.W. [et al.]. 1996.** A field guide to the tanoak and Douglas-fir plant associations in northwestern California. R5-ECOL-TP-009. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 552 p.
- Johnson, C.A. 2008.** Mammalian dispersal behavior and its fitness correlates. Guelph, ON, Canada: University of Guelph. 140 p. Ph.D. dissertation.
- Johnson, C.A.; Fryxell, J.M.; Thompson, I.D.; Baker, J.A. 2009.** Mortality risk increases with natal dispersal in American martens. *Proceedings of the Royal Society of Biological Sciences*. 276: 3361–3367.
- Johnson, D.H. 1980.** The comparison of usage and availability measurements for evaluating resource preference. *Ecology*. 61(1): 65–71.

- Johnstone, J.A.; Dawson, T.E. 2010.** Climatic context and ecological implications of summer fog decline in the coast Redwood Region. *Proceedings of the National Academy of Sciences of the United States of America*. 107: 4533–4538.
- Kartashov, L.M. 1989.** Age-changes in fertility of sables (*Martes zibellina*) in the central Ob Region. *Soviet Journal of Ecology* (in Russian with English summary). 20: 70–74.
- Katnik, D.D.; Harrison, D.J.; Hodgman, T.P. 1994.** Spatial relations in a harvested population of martens in Maine. *Journal of Wildlife Management*. 58: 600–607.
- Kimmerer, R.; Lake, F.K. 2001.** The role of indigenous burning in land management. *Journal of Forestry*. 99(11): 36–41.
- King, C.M.; Powell, R.A. 2006.** The natural history of weasels and stoats: ecology, behavior and management, 2nd ed. New York: Oxford University Press: 464 p.
- 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.
- Krohn, W.B.; Hoving, C.; Harrison, D. [et al.]. 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, Inc: 115–131.
- 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.N.; Woodard, P.M. eds. *Martes: taxonomy, ecology, techniques, and management*. Edmonton, AB, Canada: Provincial Museum of Alberta: 211–232.
- Kyle, C.J.; Strobeck, C. 2003.** Genetic homogeneity of Canadian mainland marten populations underscores the distinctiveness of Newfoundland pine martens (*Martes americana atrata*). *Canadian Journal of Zoology*. 81: 57–66.
- Lake, F. 2007.** Traditional ecological knowledge to develop and maintain fire regimes in northwestern California, Klamath-Siskiyou Bioregion: management and restoration of culturally significant habitats. Corvallis, OR: Oregon State University. 732 p. Ph.D. dissertation.

- Larivière, S. 1999.** *Mustela vison*. Mammalian Species. 608: 1–9.
- Lessa, E.P.; Cook, J.A.; Patton, J.L. 2003.** Genetic footprints of demographic expansion in North America, but not Amazonia, following the Late Pleistocene. *Proceedings of the National Academy of Sciences of the United States of America*. 100: 10331–10334.
- Lewis, H.T. 1993.** Patterns of Indian burning in California: ecology and ethnohistory. In: Blackburn, T.C.; Anderson, K., eds. *Before the wilderness: environmental management by Native Californians*. Menlo Park, CA: Ballena Press: 55–116.
- Linnell, M.A.; Moriarty, K.M.; Green, D.S.; Levi, T. [N.d.].** Density and population viability of coastal marten: a rare and geographically isolated small carnivore. Manuscript in preparation. On file with: M. Linnell, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331.
- Lorimer, C.G.; Porter, D.J.; Madej, M.A. [et al.]. 2009.** Presettlement and modern disturbance regimes in coast redwood forests: implications for the conservation of old-growth stands. *Forest Ecology and Management*. 258: 1038–1054.
- Luoma, D.L.; Trappe, J.M.; Claridge, A.W. [et al.]. 2003.** Relationships among fungi and small mammals in forested ecosystems. In: Zabel, C.J.; Anthony, R.G. eds. *Mammal community dynamics: management and conservation in the coniferous forests of western North America*. Cambridge, United Kingdom: Cambridge University Press: 343–373.
- Markley, M.H.; Bassett, C.F. 1942.** Habits of captive marten. *American Midland Naturalist*. 28(3): 604–616.
- Marshall, D.B. 1994.** Status of the American marten in Oregon and Washington. Portland, OR: Audubon Society. 37 p.
- Martin, S.K. 1994.** Feeding ecology of American martens and fishers. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A, eds. *Martens, sables, and fishers: biology and conservation*. Ithaca, NY: Cornell University Press: 297–315.
- Master, L.L.; Faber-Langendoen, D.; Bittman, R. [et al.]. 2012.** NatureServe conservation status assessments: factors for evaluating species and ecosystem risk. Arlington, VA: NatureServe, 64 p.
- McCann, N.P.; Zollner, P.A.; Gilbert, J.H. 2010.** Survival of adult martens in northern Wisconsin. *Journal of Wildlife Management*. 74(7): 1502–1507.

- McGowan, C.; Howes, L.A.; Davidson, W.S. 1999.** Genetic analysis of an endangered pine marten (*Martes americana*) population from Newfoundland using randomly amplified polymorphic DNA markers. *Canadian Journal of Zoology*. 77: 661–666.
- Mead, R.A. 1994.** Reproduction in *Martes*. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A., eds. *Martens, sables, and fishers: biology and conservation*. Ithaca, NY: Cornell University Press: 404–422.
- Miller, J.D.; Safford, H.D.; Crimmins, M.; Thode, A.E. 2009.** Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. *Ecosystems*. 12: 16–32.
- Miller, J.D.; Skinner, C.; Safford, H. [et al.]. 2012.** Trends and causes of severity, size, and number of fires in northwestern California, USA. *Ecological Applications*. 22: 184–203.
- Mills, L.S. 2007.** Conservation of wildlife populations: demography, genetics, and management. Hoboken, NJ: Blackwell Press. 424 p.
- Moriarty, K.; Bailey, J.; Smythe, S.; Verschuyt, J. 2016.** Distribution of Pacific marten in Coastal Oregon. *Northwestern Naturalist*. 97(2): 71–81.
- Moriarty, K.; Zielinski, W.J.; Epps, C. 2014.** Pacific marten (*Martes caurina*) habitat use and movement in Lassen National Forest, California. Unpublished report. On file with: Oregon State University, 1500 SW Jefferson Street, Corvallis, OR 97331.
- Morris, W.G. 1934.** Lightning storms and fires on the national forests of Oregon and Washington. *Monthly Weather Review*. 62: 370–375.
- Monitoring Trends in Burn Severity [MTBS]. 2015.** National burned area boundaries dataset: 1984 to 2014. <http://www.mtbs.gov/dataaccess.html>. (27 August 2015).
- Naney, R.N.; Finley, L.L.; Lofroth, E.C. [et al.]. 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.
- Norman, S.P. 2007.** A 500-year record of fire from a humid coast redwood forest. Report to Save-the-Redwoods League, 34 p. https://www.savetheredwoods.org/wp-content/uploads/pdf_norman.pdf. (15 August 2018).

- Odion, D.C.; Frost, E.J.; Strittholt, J.R. [et al.]. 2004.** Patterns of fire severity and forest conditions in the western Klamath Mountains, California. *Conservation Biology*. 18: 927–936.
- Ohmann, J.L.; Gregory, M.J. 2002.** Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, USA. *Canadian Journal of Forest Research*. 32(4): 725–741.
- Ohmann, J.L.; Spies, T.A. 1998.** Regional gradient analysis and spatial pattern of woody plant communities of Oregon forests. *Ecological Monographs*. 68(2): 151–182.
- Oneal, C.B.; Stuart, J.D.; Steinberg, S.J.; Fox, L. 2006.** Geographic analysis of natural fire rotation in the California redwood forests during the suppression era. *Fire Ecology*. 2: 73–99.
- Oregon Administrative Rule [OAR] 635-050-0050.** Oregon’s threatened and endangered species rule. <https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=169222>. (15 June 2018).
- Oregon Administrative Rule [OAR] 635-100-0040.** Oregon’s sensitive species rule. <https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=173209>. (15 June 2018).
- Oregon Conservation Strategy [OCS]. 2016.** Salem, OR: Oregon Department of Fish and Wildlife. <http://www.oregonconservationstrategy.org>. (15 June 2018).
- Pauli, J.N.; Smith, W.P.; Ben-David, M. 2012.** Quantifying dispersal rates and distances in North American martens: a test of enriched isotope labeling. *Journal of Mammalogy*. 93: 390–398.
- Phillips, D.M. 1994.** Social and spatial characteristics, and dispersal of marten in a forest preserve and industrial forest. Orono, ME: University of Maine. 95 p. M.S. thesis.
- Poole, K.G.; Porter, A.D.; Vries, A.D. [et al.]. 2004.** Suitability of a young deciduous-dominated forest for American marten and the effects of forest removal. *Canadian Journal of Zoology*. 82(3): 423–435.
- Potvin, F.; Belanger, L.; Lowell, K. 2000.** Marten habitat selection in a clearcut boreal landscape. *Conservation Biology*. 14: 844–857.

- Potvin, F.; Breton, L. 1997.** Short-term effects of clear-cutting on martens and their prey in the boreal forest of western Quebec. In: Proulx, G.; Bryant, H.N.; Woodard, P.M., eds. *Martes: taxonomy, ecology, techniques, and management*. Edmonton, AB, Canada: Provincial Museum of Alberta: 452–474.
- Powell, R.A. 1994.** Structure and spacing of *Martes* populations. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A., eds. *Martens, sables, and fishers: biology and conservation*. Ithaca, NY: Cornell University Press: 101–121.
- 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.
- PRBO Conservation Science [PRBO]. 2011.** Projected effects of climate change in California: ecoregional summaries emphasizing consequences for wildlife. Version 1.0. <http://data.prbo.org/apps/bssc/climatechange>. (November 2011).
- PRISM Climate Group. 2012.** <http://www.prism.oregonstate.edu/>. (23 January 2018).
- Raphael, M.G.; Jones, L.C. 1997.** Characteristics of resting and denning sites of American martens in central Oregon and western Washington. In: Proulx, G.; Bryant, H.N.; Woodard, P.M., eds. *Martes: taxonomy, ecology, techniques, and management*. Edmonton, AB, Canada: Provincial Museum of Alberta: 146–165.
- Ricketts, T.H.; Dinerstein, E.; Olson, D.M. [et al.]. 1999.** Terrestrial ecoregions of North America: a conservation assessment. Covelo, CA: Island Press. 508 p.
- Ripple, W.J. 1994.** Historic spatial patterns of old forests of western Oregon. *Journal of Forestry*. 92: 45–49.
- Rizzo, D.M.; Garbelotto, M. 2003.** Sudden oak death: endangering California and Oregon forest ecosystems. *Frontiers in Ecology and the Environment*. 1(4): 197–204.
- Rosenberg, D.K.; Swindle, K.A.; Anthony, R.G. 1994.** Habitat associations of California red-backed voles in young and old-growth forests in western Oregon. *Northwest Science*. 68(4): 266–272.
- Ruggiero, L.F.; Pearson, D.E.; Henry, S.E. 1998.** Characteristics of American marten dens in Wyoming. *Journal of Wildlife Management*. 62(2): 663–673.

- Ruth, R.H.; Harris, A.S. 1979.** Management of western hemlock-Sitka spruce forest for timber production. Gen. Tech. Rep. PNW-88. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 197 p.
- Safford, H.D.; van de Water, K.; Schmidt, D. 2010.** California fire return interval departure (FRID) map, 2010 version. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region and The Nature Conservancy—California. <http://www.fs.fed.us/r5/rsl/clearinghouse/r5gis/frid/>.
- Salafsky, N.; Salzer, D.; Stattersfield, A.J. [et al.]. 2008.** A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conservation Biology*. 22: 897–911.
- Save the Redwoods League. 2015.** Coast redwoods facts. <http://www.savetheredwoods.org/redwoods/coast-redwoods/>. (19 September 2017).
- Sawyer, J.O. 2007.** Forests of northwestern California. In: Barbour, M.G.; Keeler-Wolf, T.; Schoenherr, A.A., eds. *Terrestrial vegetation of California*, 3rd ed. Berkeley, CA: University of California Press: 253–295.
- Sawyer, J.O.; Sillett, S.C.; Libby, W.J. [et al.]. 2000a.** Redwood trees, communities, and ecosystems: a closer look. In: Noss, R.L. ed. *The redwood forest: history, ecology, and conservation of the coast redwoods*. Washington, DC: Island Press: 81–118.
- Sawyer, J.O.; Sillett, S.C.; Popenoe, J.H. [et al.]. 2000b.** Characteristics of redwood forests. In: Noss, R.L. ed. *The redwood forest: history, ecology, and conservation of the coast redwoods*. Washington, DC: Island Press: 39–80.
- Schumacher, T.V. 1999.** A multi-scale analysis of habitat selection at den and resting sites of American martens in southeast Alaska. Laramie, WY: University of Wyoming. 90 p. M.S. thesis.
- Schwartz, M.K.; Slauson, K.M.; Pilgrim, K.; Zielinski, W.J. [et al.]. 2016.** Genomic evidence showing the California coast/Oregon coast populations of pacific marten representing a single conservation unit. 38 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 800 E Beckwith Avenue, Missoula, MT 59802.
- Self, S.; Kerns, S. 2001.** Pine marten use of a managed forest landscape in northern California. Wildland Research Paper No. 4. Redding, CA: Sierra Pacific Industries Sierra Pacific Industries. 13 p.

- Sillett, S.C.; Van Pelt, R.V. 2007.** Trunk reiteration promotes epiphytes and water storage in an old-growth redwood forest canopy. *Ecological Monographs*. 77(3): 335–359.
- Simon, T.L. 1980.** An ecological study of the pine marten in the Tahoe National Forest. Sacramento, CA: California State University. 187 p. M.S. thesis.
- Slauson, K.M. 2003.** Habitat selection by American martens (*Martes americana*) in coastal northwestern California. Corvallis, OR: Oregon State University. 112 p. M.S. thesis.
- Slauson, K.M. 2012.** Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Slauson, K.M. 2015.** Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Slauson, K.M. 2017.** Linking landscape pattern to population processes in a carnivorous mammal. Missoula, MT: University of Montana. 173 p. Ph.D. dissertation.
- Slauson, K.M. [N.d.].** Diet, distribution, and habitat selection by bobcats in the coastal forests of northwestern California. Manuscript in preparation. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Slauson, K.M.; Baldwin, J.A.; Zielinski, W.J. 2009a.** Status and estimated size of the only remnant population of the Humboldt subspecies of the American marten (*Martes americana humboldtensis*) in northwestern California. 28 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Slauson, K.M.; Zielinski, W.J. 2001.** Distribution and habitat ecology of American martens and Pacific fishers in southwestern Oregon. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.

- Slauson, K.M.; Zielinski, W.J. 2004.** Conservation status of American martens and fishers in the Klamath-Siskiyou bioregion. In: Merganther, K.; Williams, J.; Jules, E., eds. Proceedings of the 2nd conference on Klamath-Siskiyou ecology, Cave Junction, OR: Siskiyou Field Institute: 60–70.
- Slauson, K.M.; Zielinski, W.J. 2007.** The relationship between the understory shrub component of coastal forests and the conservation of forest carnivores. In: Standiford, R.B.; Giusti, G.A.; Valachovic, Y. [et al.], tech. eds. Proceedings of the redwood region forest science symposium: What does the future hold? Gen. Tech. Rep. PSW-GTR-194. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 241–243.
- Slauson, K.M.; Zielinski, W.J. 2009.** Characteristics of summer/fall resting structures used by American martens in coastal northwestern California. Northwest Science. 83: 35–45.
- Slauson, K.M.; Zielinski, W.J. 2010.** The effects of forest thinning and fuels reduction on American martens in the southern Cascades region of California: Fieldwork summary II, High Grouse and Hoffman study areas, 2008–2010. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Slauson, K.M.; Zielinski, W.J. 2017.** Seasonal specialization in diet of the Humboldt marten (*Martes caurina humboldtensis*) in California and the importance of prey size. Journal of Mammology. 98(6): 1697–1708.
- Slauson, K.M.; Zielinski, W.J.; Early, D.A. [et al.]. 2014.** Humboldt marten dispersal and movement ecology study: Progress Report. 6 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Slauson, K.M.; Zielinski, W.J.; Hayes, J.P. 2007.** Habitat selection by American martens in coastal California. Journal of Wildlife Management. 71: 458–468.
- Slauson, K.M.; Zielinski, W.J.; Kirk, T.A. 2010.** Effects of forest restoration on mesocarnivores in the northern Redwood Region of northwestern California. 29 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.

- Slauson, K.M.; Zielinski, W.J.; LaPlante, D.; Kirk, T. [N.d.].** Landscape habitat suitability model for the Humboldt marten (*Martes caurina humboldtensis*). Northwest Science. Manuscript in preparation. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Slauson, K.M.; Zielinski, W.J.; Stone, K.D. 2009b.** Characterizing the molecular variation between American marten (*Martes americana*) subspecies from Oregon and California. *Conservation Genetics*. 10: 1337–1341.
- Slough, B.G. 1989.** Movements and habitat use by transplanted marten in the Yukon Territory. *Journal of Wildlife Management*. 53: 991–997.
- Smith, J.E.; Molina, R.; Huso, M.M.P. [et al.]. 2002.** Species richness, abundance, and composition of hypogeous and epigeous ectomycorrhizal fungal sporocarps in young, rotation-age, and old-growth stands of Douglas-fir (*Pseudotsuga menziesii*) in the Cascade Range of Oregon, USA. *Canadian Journal of Botany*. 80: 186–204.
- Spencer, W.D. 1987.** Seasonal rest-site preferences of pine martens in the northern Sierra Nevada. *Journal of Wildlife Management*. 51: 616–621.
- Spencer, W.D.; Barrett, R.H.; Zielinski, W.J. 1983.** Marten habitat preferences in the northern Sierra Nevada. *Journal of Wildlife Management*. 47: 1181–1186.
- Spies, T.A.; McComb, B.C.; Kennedy, R.S.H. [et al.]. 2007.** Potential effects of forest policies on terrestrial biodiversity in a multi-ownership province. *Ecological Applications*. 17(1): 48–65.
- Stamps, J.A. 2001.** Habitat selection by dispersers: integrating proximate and ultimate approaches. In: Clobert, J.; Danchin, E.; Dhondt, A.A.; Nichols, J.D., eds. *Dispersal*. New York: Oxford University Press: 230–242.
- Strickland, M.A.; Douglas, C.W. 1987.** Marten. In: Novak, M.; Baker, J.A.; Obbard, M.E.; Malloch, B. eds. *Wild furbearer management and conservation in North America*. North Bay, ON, Canada: Ontario Trappers Association: 531–546.
- Strickland, M.A.; Douglas, C.W.; Novak, M.; Hunzinger, N.P. 1982.** Marten. In: Chapman, J.A.; Feldhamer, G.A., eds. *Wild mammals of North America—biology, management and economics*. Baltimore, MD: Johns Hopkins University Press: 599–612.
- Strittholt, J.R.; DellaSala, D.A.; Jiang, H. 2006.** Status of mature and old-growth forests in the Pacific Northwest. *Conservation Biology*. 20: 363–374.

- Stuart, J.D.; Stephens, S.L. 2006.** North coast bioregion. In: Sugihara, N.G.; van Wagtendonk, J.; Fites-Kaufmann, J. [et al.], eds. Fire in California's ecosystems. Berkeley, CA: University of California Press: 147–169.
- Sugihara, N.G.; van Wagtendonk, J.W.; Fites-Kaufman, J. 2006.** Fire as an ecological process. In: Sugihara, N.G.; van Wagtendonk, J.W.; Fites-Kaufmann, J. [et al.], eds. Fire in California's ecosystems. Berkeley, CA: University of California Press: 58–74.
- Taylor, S.L. 1993.** Thermodynamics and energetics of resting site use by the American marten (*Martes americana*). Laramie, WY: University of Wyoming. 89 p. M.S. thesis.
- Taylor, S.L.; Buskirk, S.W. 1994.** Forest microenvironments and resting energetics of the American marten *Martes americana*. *Ecography*. 17: 249–256.
- Teensma, P.D.; Rienstra, J.T.; Yeiter, M.A. 1991.** Preliminary reconstruction and analysis of change in forest stand age class of the Oregon Coast Range from 1850 to 1940. Technical Note T/N OR-9. Portland, OR: U.S. Department of the Interior, Bureau of Land Management: 19 p.
- Thompson, I.D. 1994.** Marten populations in uncut and logged boreal forests in Ontario. *Journal of Wildlife Management*. 58: 272–280.
- Thompson, I.D.; Colgan, P.W. 1987.** Numerical responses of martens to a food shortage in north-central Ontario. *Journal of Wildlife Management*. 51: 824–835.
- Thompson, I.D.; Fryxell, J.; Harrison, D.J. 2012.** Improved insights into use of habitat by American martens. In: Aubry, K.B.; Zielinski, W.J.; Raphael, M.G. [et al.], eds. Biology and conservation of martens, sables, and fishers: a new synthesis. Ithaca, NY: Cornell University Press: 209–230.
- Thompson, I.D.; Harestad, A.S. 1994.** Effects of logging on American marten with models for habitat management. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A., eds. Martens, sables, and fishers: biology and conservation. Ithaca, NY: Cornell University Press: 355–366.
- Tietz, J.R.; Johnson, M.D. 2007.** Stopover ecology and habitat selection of juvenile Swainson's thrushes during fall migration along the northern California coast. *The Condor*. 109(4): 795–807.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 2006.** Forest insect and disease conditions in the United States 2005. Washington, DC. 159 p.

U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 2014.

Draft species report: fisher (*Pekania pennati*), West Coast population. On file with: 243 p.

U.S. Department of the Interior, Fish and Wildlife Service; U.S. Department of Agriculture, Forest Service; California Department of Fish and Game; Green Diamond Resource Company [et al.] [USDI FWS et al.]. 2012.

Memorandum of Understanding on Humboldt marten conservation. On file with: U.S. Department of the Interior, Fish and Wildlife Service, Arcata Field Office, 1655 Heindon Road, Arcata, CA 95521. 16 p.

U.S. Department of the Interior, Geological Survey [USDI GS]. 2012.

LANDFIRE fire regime layer (last updated June 2013). Reston, VA. <http://landfire.cr.usgs.gov/viewer/>. (21 July 2012).

Vale, T.R., ed. 2002. Fire, native peoples and the natural landscape. Covelo, CA: Island Press: 336 p.

van Wagtenonk, J.W.; Cayan, D.R. 2008. Temporal and spatial distribution of lightning in California in relation to large-scale weather patterns. *Fire Ecology*. 4: 34–56.

Veirs, S.D. 1982. Coast redwood forest: stand dynamics, successional status, and the role of fire. In: Means, J.E., ed. *Proceedings of the symposium on forest succession and stand development in the Pacific Northwest*. Corvallis, OR: Oregon State University: 119–141.

Verts, B.J.; Carraway, L.N. 1998. Land mammals of Oregon. Berkeley, CA: University of California Press. 668 p.

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

Wengert, G.M. 2013. Ecology of intraguild predation on fishers (*Martes pennanti*) in California. Davis, CA: University of California. 119 p. Ph.D. dissertation.

Wilbert, C.J. 1992. Spatial scale and seasonality of habitat selection by martens in southeastern Wyoming. Laramie, WY: University of Wyoming. 182 p. M.S. thesis.

Wilk, R.J.; Raphael, M.G. 2018. Survival and predators of Pacific marten in a salvage-logged pine forest, south-central Oregon. *Northwest Naturalist*. 99(2): 115–123.

- Wimberly, M.C. 2002.** Spatial simulation of historical landscape patterns in coastal forests of the Pacific Northwest. *Canadian Journal of Forest Research*. 32: 1316–1328.
- Wimberly, M.C.; Spies, T.A.; Long, C.J.; Whitlock, C. 2000.** Simulating historical variability in the amount of old forests in the Oregon Coast Range. *Conservation Biology*. 14: 167–180.
- Wimberly, M.C.; Spies, T.A.; Nonaka, E. 2004.** Using criteria based on the natural fire regime to evaluate forest management in the Oregon Coast Range of the United States. In: Perera, A.H.; Buse, L.J.; Weber, M.G., eds. *Emulating natural forest landscape disturbances: concepts and applications*. New York: Columbia University Press: 146–157.
- Zabel, C.J.; Waters, J.R. 1992.** Associations between forest structure and abundances of flying squirrels and other small mammals. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Zielinski, W.J. 1984.** Plague in pine martens and the fleas associated with its occurrence. *Great Basin Naturalist*. 44(1): 170–175.
- 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(7): 1558–1571.
- Zielinski, W.J.; Slauson, K.M.; Carroll, C.R. [et al.]. 2001.** Status of American marten populations in the 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.; Slauson, K.M. [In press].** Pacific marten, *Martes caurina*. California mammal species of special concern. Sacramento, CA: California Department of Fish and Wildlife.

Appendix 1: Humboldt Marten Conservation Group

Executive Group

Richard Callas, California co-chair, California Department of Fish and Wildlife

Phil Detrich, project coordinator, PJD Environmental Consulting

Gregory Schmidt, California co-chair, U.S. Department of the Interior, Fish and Wildlife Service, Arcata Field Office

Keith Slauson, science coordinator, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station

Russ Stauff, Oregon co-chair, Oregon Department of Fish and Wildlife

James Thrailkill, Oregon co-chair, U.S. Department of the Interior, Fish and Wildlife Service, Roseburg Field Office

William Zielinski, science advisor, U.S. Department of Agriculture Forest Service, Pacific Southwest Research Station

Participants

California State Parks, Northcoast Redwoods District: Amber Transou, Jay Harris

Confederated Tribes of the Siletz Indians of Oregon: Jeanne Spaur

Green Diamond Resource Company: Keith Hamm, Desiree Early

Hancock Forest Management: Tim McBride

Lowell Diller Consulting: Lowell Diller

National Council for Air and Stream Improvement: Jake Verschuyt

National Park Service, Redwood National Park: Dave Roemer, Kristin Schmidt

Oregon Department of Fish and Wildlife: Rod Krahmer

Oregon Department of Forestry: Nick Palozzotto, Randy Smith, Jennifer Weikel

Oregon Parks and Recreation Department: Vanessa Blackstone

Plum Creek Timber: Jeff Light, Ron Stiener

Roseburg Forest Products: Rich Klug

Save the Redwoods League: Richard Campbell

U.S. Department of the Interior, Bureau of Land Management: Scott Hopkins, Rex McGraw, Randall Miller, Roy Price, Robin Snider

U.S. Department of the Interior, Fish and Wildlife Service, Arcata Field Office:
Bruce Bingham, Kathleen Brubaker

U.S. Department of the Interior, Fish and Wildlife Service, Oregon Fish and
Wildlife Office: Sue Livingston

U.S. Department of Agriculture, Forest Service, Pacific Northwest Research
Station: Katie Moriarty

U.S. Department of Agriculture, Forest Service, Siskiyou National Forest:
Dave Clayton

U.S. Department of Agriculture, Forest Service, Six Rivers National Forest:
Brenda Devlin-Craig

U.S. Department of Agriculture, Forest Service, Siuslaw National Forest:
Deanna Williams

Weyerhaeuser Company: Matt Hane, Mike Rochelle

Yurok Tribe: Kent Barnes, Jim Erler, Chris West

Appendix 2: Summary of threats to the Humboldt marten, rationale for scope and severity rankings in California, and supplemental information used for their evaluation

Potential threat

Habitat loss and degradation:

Wildfire—

Proportion of area affected by wildfire(s)—

Scope: Recent fires have been large enough that a single fire in the extant population area (EPA) could burn 31 to 70 percent of the area, and one or more fires in the population reestablishment areas/landscape connectivity area (PRAs/LCA) could realistically affect 11 to 30 percent of the habitat over the next 15 years.

Severity: Low-intensity fires have the potential to degrade marten habitat over the short term through the reduction of shrub cover. High-severity fires or the proportions of fires with high severity have the potential to cause long-term habitat degradation by causing high or complete overstory mortality in suitable habitat. All fires have the potential to cause at least short-term habitat degradation.

Emergency fire suppression—

Scope: Decisions made during efforts to contain wildfire may result in further loss or degradation of habitat, for example, through back burning and containment line creation. Based on the sizes of recent fires and areas included in back burning suppression efforts, 11 to 30 percent of the EPAs and 1 to 10 percent of the PRAs and LCAs could be potentially affected over the next 15 years by suppression efforts. Wildfires burned approximately 17 percent of the moderate- and high-suitability Humboldt marten (*Martes caurina humboldtensis*) habitat within the North Coastal California EPA between 2000 and 2014 (i.e., the previous 15 years), with a single large fire (the Blue 2 Fire in 2008) (MTBS 2015) responsible for nearly all burned suitable habitat. No large fires burned within the California-Oregon Border EPA during the past 15 years (i.e., 2000–2014) (MTBS 2015); however, a single large fire in 1987 (the Longwood Fire) (MTBS 2015) burned approximately 12 percent of the moderate- and high-suitability Humboldt marten habitat within the California-Oregon border EPA.

Severity: The severity ranks mirror those of wildfire owing to their similar effects on habitat.

Postfire salvage logging—

Scope: There is some uncertainty in the potential scope for this threat, owing to variable use of postfire salvage following recent fires. We chose the scope value based on the potential amount of area that could be affected if salvage logging were to match the areal extent of salvage in the Biscuit Fire area. Note that under the California Forest Practices Rules, “substantially damaged” private lands can be completely salvaged after wildfire; the extent to which this might occur in the assessment area is unknown.

Potential threat

Severity: The removal of large-diameter dead or declining trees represents a high degree of habitat degradation.

Lack of fire as a disturbance process—

Scope and severity: In most of the EPAs, PRAs, and LCAs that are exposed to summer fog, fire has not been excluded long enough to have resulted in any significant losses of the functional role fire plays in creating key marten habitat elements such as snag recruitment. In more inland areas outside the influence of summer fog, one or more fire-return intervals may have been missed, resulting in the accumulation of fuels that may increase the risk of fires with higher intensity and larger area.

Forest management:

Management of early-successional forests (≤60 years old)—

Overstory removal (logging):

Scope: Harvest of early-successional stands is likely to only occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.

Severity: While early-successional forests are not considered suitable marten habitat, harvesting early successional stands using even-age management increases the length of time before suitable habitat can be recruited. Where this occurs adjacent to currently suitable habitat or in areas of important connectivity, the action degrades the adjacent suitable habitat and areas of habitat connectivity.

Thinning (precommercial, commercial, restoration)—

Scope: Thinning is likely to occur in many areas of young forest in both the EPAs and PRAs, and LCA over the next 15 years.

Severity: Most thinning of young dense forest stands is likely beneficial for marten habitat recruitment and thus has the lowest severity rank.

Shrub^a layer reduction—

Scope: Shrub layer reduction, for either fuels reduction or for reducing competition with conifer regeneration, is likely to occur in limited areas of the EPAs, PRAs, and LCAs over the next 15 years.

Severity: The loss or reduction of the shrub layer is a significant degradation of habitat.

Reduction of large residual structures (live trees, logs, snags)—

Scope: The harvest of residual large live conifers, through selection harvest, is likely to occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.

Severity: Removal of large-diameter structures is a significant degradation of habitat.

Reduction of hardwoods—

Scope: Activities that remove hardwoods to reduce competition with conifers are likely to occur in a small proportion of the EPAs, PRAs, and LCA.

Severity: Hardwoods, specifically tanoak (*Notholithocarpus densiflorus*) Hook & Arn. P.S. Manos C.H. Cannon, & S.H. oh and golden chinquapin, (*Chrysopsis chrysophylla*) are important species for providing marten den and rest sites as well as mast for prey species. The reduction of hardwoods below their natural levels of abundance, based on site conditions, represents a degradation of habitat.

Potential threat

Management of mid-successional forests (60 to 120 years old)—

Overstory removal (logging)—

- Scope: Harvest of mid-successional forests is likely to occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.
- Severity: Where it occurs adjacent to older stands or in important areas of habitat connectivity, mid-successional habitat can be used by martens. This successional stage also is important for future recruitment into highly suitable late-successional habitat. Loss of mid-successional forest in key areas of the EPA, PRAs, and LCA represents significant habitat degradation.

Thinning (commercial, restoration)—

- Scope: Thinning is likely to occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.
- Severity: The severity of the impact of thinning depends on the extent, the proportion of overstory removed, the size of trees removed, and the resulting stand structure. Restoration thinning prescriptions that reduce unnaturally dense stands by removing smaller diameter trees and create more stand heterogeneity are likely to be beneficial. However, we consider here the impacts of commercial thinning prescriptions, where the largest diameter trees are harvested, uniform tree spacing is created, resulting in a homogeneous stand structure. Where these outcomes result in association with suitable habitat or in areas important for connectivity, they may represent moderate to serious habitat degradation.

Shrub^a layer reduction—

- Scope: Shrub layer reduction is likely to occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.
- Severity: The loss or reduction of the mesic ericaceous shrub layer represents a significant degradation of habitat.

Reduction of large structures (live trees, logs, snags)—

- Scope: Reduction of large structures in mid-successional forest is likely to occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.
- Severity: Removal of large-diameter structures in mid-successional forest would result in a significant degradation of habitat.

Reduction of hardwoods—

- Scope: Reduction of hardwoods is likely to occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.
- Severity: Hardwoods, specifically tanoak and chinquapin, are important species for providing den and rest sites as well as mast for prey species. The reduction of hardwoods below their natural levels of abundance represents a degradation of habitat.

Removal of late successional forest (>120 to 150 years old):

- Scope: Logging of late-successional forest is uncommon in most areas of the EPAs, PRAs, or LCA.
- Severity: Where logging of late-successional forest occurs, it results in either habitat loss or a high level of degradation, depending on the harvest method used.

Potential threat

Human development (urbanization, road construction, recreation, agriculture, large reservoirs)—

- Scope: Human development is likely to occur in a small proportion of the EPAs, PRAs, and LCA over the next 15 years.
- Severity: Human development typically results in the direct loss or significant modification of habitat.

Cumulative effects of habitat loss and degradation leading to large-scale fragmentation of suitable habitat—

- Scope: The cumulative effects of habitat loss and degradation leading to large-scale fragmentation of suitable habitat are likely to continue to affect the majority of the EPAs, and a high proportion of suitable habitat in the PRAs and LCA over the next 15 years. We consider both past effects and those likely to occur over the next 15 years to be contributors to the scope of this threat.
- Severity: The combination of past and future cumulative effects of habitat loss and degradation leading to large-scale fragmentation of suitable habitat is likely to result in the continued degraded state or increase landscape-scale habitat degradation over the next 15 years.

Climate change effects on habitat loss:

Climate change: mid-21st century (2040–2060)—

- Scope: Climate change under short-term projections is likely to affect the more inland portions of the EPAs, PRAs, and LCA.
- Severity: The potential short-term impacts of climate change may lead to slight changes that include increases in temperatures and reductions in moisture, including both rainfall and fog that may directly or indirectly contribute to the slight degradation of habitat.

Climate change: late 21st century (2080–2100)—

- Scope: Over the longer term, climate change is likely to affect the majority of EPAs, PRAs, and LCA.
- Severity: Longer-term impacts are likely to be more severe in the inland areas, including much of the PRAs, and to be less significant contributors to habitat degradation in the EPAs and LCA.

Reduction in marten survival and reproduction—

Incidental capture during legal trapping of fur bearers—

- Scope: Martens are not legally trapped in California and few trappers pursuing legally trapped species are expected to be active in the EPAs, PRAs, or LCA over the next 15 years, based on recent trapping activity trends (R. Callas, California Department of Fish and Wildlife, pers. comm.).
- Severity: Incidental capture by trappers using live traps is not likely to cause mortality but may involve minor injury.

Research activities (live trapping, radio-collaring)—

- Scope: Research activities are not likely to be conducted in more than 10 percent of the population over the next 15 years.

Potential threat

Severity: While the potential for injury or mortality occurs during live capture, chemical immobilization, and radio-collaring, mortalities or significant injuries attributed to recent research activities for the Humboldt marten or elsewhere in California have been rare.

Collision with vehicles:

Scope: Small portions of the EPAs, PRAs, and LCA include roads with frequent high-speed traffic.

Severity: Collision with vehicles is likely to result in mortality.

Exposure to toxicants (primarily rodenticides from illegal marijuana cultivation sites):

Scope: There is some uncertainty as to the extent to which the EPAs, PRAs, and LCA are affected by illegal marijuana cultivation where toxicants are used. Based on known locations of illegal marijuana cultivation, we consider some portion of each area to be affected. Law enforcement personnel within northern coastal California estimated that they find a relatively low percentage (approximately 15 percent) of illegal marijuana cultivation sites. Further, law enforcement is only able to remediate (i.e., cleaning up toxicants at discovered sites) at a fraction of the illegal cultivation sites that are found. To our knowledge, there have been no systematic surveys of the distribution or abundance of illegal marijuana cultivation sites within the two EPAs in northern coastal California. The “restricted” scope (11–30 percent of a population or suitable habitat affected) assigned to this potential threat reflects our assumption that the relatively remote location of the two California EPAs and the dense shrub layer found in suitable Humboldt marten habitat would lower the suitability of these areas for marijuana cultivation.

Severity: Exposure to toxicants is serious and likely involves direct mortality or indirect mortality by compromising exposed animal’s immune system or motor function for most individuals exposed. To date, seven dead Humboldt martens have been tested for rodenticide exposure (all from the North Coastal California EPAs), one of which tested positive with a sublethal concentration (K. Slauson, unpublished data). That marten was killed by a bobcat; whether the sublethal dose of rodenticide predisposed that marten to predation is unknown.

Lethal diseases:

Scope: Lethal diseases, both natural and human influenced, have the potential to affect most of the areas of the EPAs and smaller portions of the PRAs and LCA over the next 15 years.

Severity: Lethal diseases have serious impacts, typically resulting in mortality for most individuals.

Human-influenced predation (i.e., habitat modification favoring marten predators):

Scope: Predation has emerged as a likely limiting factor for marten population growth and expansion. Marten predators such as bobcats primarily prey on species closely associated with early-seral habitat conditions. Even-aged forest management creates and can perpetuate the presence of early-seral habitat that supports marten predators. We consider both the temporary effects of existing early-seral habitat and the potential for creation of additional early-seral habitat in this threat. Human-influenced predation is likely to impact some portions of the EPAs, PRAs, and LCA over the next 15 years.

Severity: Greater distribution and abundance of marten predators increases predation risk and reduction in survivorship, and is a serious impact where it occurs.

Potential threat

Threats related to small and disjunct populations

Inbreeding depression:

Scope: It is uncertain whether inbreeding depression is occurring within the North Coastal California EPAs. However, the small population size and apparent period of isolation from other populations provide the conditions for the significant loss of genetic diversity. If inbreeding depression is occurring, it is likely to affect most of the individuals in the EPAs.

Severity: Due to the uncertainty in the degree of genetic diversity that may have been lost, we estimate that while most individuals may have reduced genetic variability, deleterious effects from loss of genetic diversity are only manifesting in some, but not all, individuals in the EPAs.

Demographic stochasticity (i.e., environmental variation affecting survival and reproduction):

Scope: The threat is an inherent risk to small populations with the potential to affect some individuals over the next 15 years.

Severity: Short-term stochasticity is only likely to affect individuals for a portion of their lives, and thus for individuals has a moderate severity.

^a Refers to the dense mesic shrub layer required by the Humboldt marten.

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at http://www.ascr.usda.gov/complaint_filing_cust.html and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

