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# Martes americana

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# INTRODUCTORY

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Photo by Nathan Stone

AUTHORSHIP AND CITATION:

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Mountain Research Station, Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/animals/mammal/maam/all.html [2018, December 10].

FEIS ABBREVIATION:
MAAM

COMMON NAMES:
American marten

TAXONOMY:
The scientific name of the American marten is *Martes americana* (Turton) (Mustelidae) [38,184].

As many as 14 American marten subspecies have been recognized in the past. Some authorities suggest that subspecies partitioning was completely arbitrary, noting that many of the differences between subspecies were relicts of small sample size, variable coat color, or inadequate sampling. Two subspecies groups have been tentatively recognized based on cranial characters, fossil history [38], and mitochondrial DNA analyses [31]. The groups intergrade morphologically and genetically, indicating hybridization [136].

*Martes americana americana* subspecies group, including:
*Martes americana abieticola* Preble
*Martes americana abietinoides* Gray
*Martes americana actuosa* (Osgood)
*Martes americana americana* (Turton)
*Martes americana atrata* (Bangs)
*Martes americana brumalis* Bangs
*Martes americana kenaiensis* (Elliot) [136]

*Martes americana caurina* subspecies group, including:
*Martes americana caurina* (Merriam)
*Martes americana humboldtensis* Grinnell and Dixon
*Martes americana nesophila* (Osgood)
*Martes americana origenes* Rhoads
*Martes americana vancouverensis* Grinnell and Dixon
*Martes americana vulpina* (Rafinesque)
*Martes americana sierrae* Grinnell and Storer [136]

Because most studies do not indicate subspecies or subspecies group, this review synthesizes information about the American marten at the species level.

SYNONYMS:
None

ORDER:
Carnivora

CLASS:
Mammal

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# DISTRIBUTION AND OCCURRENCE

SPECIES: Martes americana

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- GENERAL DISTRIBUTION
- PLANT COMMUNITIES

GENERAL DISTRIBUTION:
The American marten is broadly distributed in northern North America. From north to south its range extends from the northern limit of treeline in arctic Alaska and Canada to northern New Mexico. From east to west its distribution extends from Newfoundland to California. In Canada and Alaska, American marten distribution is vast and continuous. In the western United States, American marten distribution is limited to mountain ranges that provide preferred habitat. Over time, the distribution of American marten has contracted and expanded regionally, with local extirpations and successful recolonizations occurring in the Great Lakes region and some parts of the Northeast (review by [28]). The American marten has been reintroduced in several areas where extirpation occurred (reviewed by [38]). NatureServe provides a distributional map of American marten.

PLANT COMMUNITIES:
The American marten inhabits coniferous and mixed coniferous-deciduous forests throughout the northern United States and Canada. In western North America, plant communities inhabited by American marten tend to be largely coniferous forests. In central and eastern North America, American marten also occupy coniferous forests, but deciduous communities may make up a large proportion of American marten habitats.

**United States:** Descriptions of plant communities occupied by American marten in the United States are organized into the following geographic areas: Alaska, Northeast, Great Lakes, Northern and Central Rockies, Pacific Northwest, California, Southwest.

Alaska: In Alaska, American marten inhabit coniferous forests largely dominated by black and white spruce, with inclusions or mixtures of western hemlock (*Tsuga heterophylla*), mountain hemlock (*Tsuga mertensiana*), Sitka spruce (*Picea sitchensis*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and/or balsam poplar (*P. balsamifera* subsp. *balsamifera*) [5,8,24,65,148,150,178]. American marten may also inhabit herbaceous and low shrub meadows [24], shrub communities near treeline containing Sitka alder (*Alnus viridis* subsp. *sinuata*) and willow (*Salix* spp.) [8], and postfire shrub-sapling plant communities containing bog birch (*Betula glandulosa*), Labrador tea (*Ledum* spp.) and blueberry (*Vaccinium* spp.) [150]. On Chichagof Island, southeast Alaska, American marten occupy coniferous rainforest plant communities containing Sitka spruce, western hemlock, mountain hemlock and Alaska-cedar (*Chamaecyparis nootkatensis*) [9,83].

Northeast: In Maine, American marten inhabit coniferous, deciduous, and mixed coniferous-deciduous forests. Conifer forests with American marten are often dominated by balsam fir (*Abies balsamea*) [35,36,61,85,90,126,128,129,158,188] and red spruce (*Picea rubens*) [35,36,61,90,126,127,128,129,158], but may also contain eastern white pine (*Pinus strobus*), eastern hemlock (*Tsuga canadensis*), black spruce (*Picea mariana*), tamarack (*Larix laricina*), and northern whitecedar (*Thuja occidentalis*) [35,36,61,126,127,128,129,158,187,188]. Deciduous forests are typically mixed communities of American beech (*Fagus grandifolia*), paper birch, sugar maple (*Acer saccharum*), red maple (*A. rubrum*), yellow birch (*Betula alleghaniensis*) [35,36,61,126,127,129], bigtooth aspen (*Populus grandidentata*) [36], and/or quaking aspen [90].

Great Lakes: In the Great Lakes region, American marten occur in coniferous, deciduous, and mixed coniferous-deciduous forests. Conifer forests inhabited by American marten in Michigan and Wisconsin contain mixed or pure stands of northern whitecedar, eastern hemlock, balsam fir, black spruce, white spruce (*Picea glauca*), eastern white pine, red pine (*Pinus resinosa*), and tamarack ([63,168,186], review by [69]). Deciduous forests inhabited by American marten in the Great Lakes region include mixtures of basswood (*Tilia americana*), northern red oak (*Quercus rubra*), sugar maple, red maple, paper birch, yellow birch, white ash (*Fraxinus americana*), and/or aspen (*Populus* spp.) [63,168,186].

Northern and Central Rockies: In the Northern and Central Rocky Mountains, plant communities occupied by American marten are largely coniferous. American marten inhabit Engelmann spruce-subalpine fir (*Picea engelmannii-Abies lasiocarpa*) plant communities in Colorado [7], Idaho [81,93,96,176,180], Montana [23,43,44,181], and Wyoming [39,45,81,82,120,149,182]. American marten are also found in lodgepole pine (*Pinus contorta*) forests in Idaho [81,93,96,110], Montana [23,43,44,181], Utah [71,75], and Wyoming [39,45,81,82,120,149,182]. American marten may also be found in pure or mixed stands of western larch (*Larix occidentalis*) [23,57,110,176,180,181], Douglas-fir (*Pseudotsuga menziesii*) [23,39,43,44,57,81,110,176,180], ponderosa pine (*Pinus ponderosa*) [23,54,110,180], western redcedar (*Thuja plicata*) [57,176,180], grand fir (*A. grandis*) [180], western hemlock [176,180], and/or limber pine (*P. flexilis*) [182]. It may also occupy mixed coniferous forests with isolated deciduous components, including quaking aspen [7,81,180,182], paper birch, and/or black cottonwood (*Populus balsamifera* subsp. *trichocarpa*) [180].

Pacific Northwest: In Washington, American marten inhabit coniferous forests dominated by western hemlock, Pacific silver fir (*Abies amabilis*) [117,143], mountain hemlock [117], lodgepole pine, Engelmann spruce-subalpine fir, and/or Douglas-fir [94]. In Oregon, American marten occupy lodgepole pine [16,143], subalpine fir, grand fir, and Douglas-fir forests [16]. In south-central Oregon, they occur in lodgepole pine-antelope bitterbrush (*Purshia tridentata*) plant communities with inclusions of ponderosa pine and western white pine [89].

California: In California, American marten occupy several coniferous forest types, including redwood (*Sequoia sempervirens*) [153,154], Sierran mixed conifer [68,92,93,144], lodgepole pine [68,73,92,93,113,159], and pure or mixed stands of white fir (*A. concolor*) [92,93,111,144,153,159,190], California red fir (*Abies magnifica*) [68,92,111,159,190], Douglas-fir [92,153,154,190], ponderosa pine [68,92,111,190], Jeffrey pine (*P. jeffreyi*) [92,111,113,159,190], western white pine (*P. monticola*) [111,159], whitebark pine (*P. albicaulis*) [74], and mountain hemlock [73,74,159].

Southwest: In the Southwest, American marten occur in spruce-fir (*Picea*-*Abies*) forests that may contain stands of quaking aspen [55].

**Canada:** In eastern Canada, American marten are found in coniferous, deciduous, and mixed coniferous-deciduous forests. In southeastern Quebec, American marten inhabit a transition zone between coniferous boreal forest and deciduous forest; these mixed forests contain balsam fir, northern whitecedar, white spruce, paper birch, quaking aspen, balsam poplar, red maple, and sugar maple [64]. American marten also occupy boreal forests. In north-central Ontario boreal forests are a mixture of black spruce, white spruce, balsam fir, jack pine (*P. banksiana*), quaking aspen, balsam poplar, and paper birch [169]. Other plant communities inhabited by American marten in eastern

Canada include black spruce lowlands [13,169,171], coniferous forests of eastern white pine, red pine, white spruce, red maple, and bigtooth aspen [62], jack pine sand plains [141,142], and mixed-hardwood forests. Mixed-hardwood forests in southeastern Ontario contain paper birch, aspen, white spruce, balsam fir, sugar maple, yellow birch, and eastern hemlock [58]. Those in central Ontario contain a combination of American beech, sugar maple, yellow birch, and eastern hemlock [62].

American marten inhabit mostly coniferous forest types in western Canada. In northwestern Alberta, American marten occur in boreal forests characterized by pure and mixed stands of Engelmann spruce, white spruce, black spruce, subalpine fir, balsam fir, lodgepole pine, and quaking aspen [138]. In British Columbia, American marten inhabit mixed- or mostly pure conifer forests including Douglas-fir-lodgepole pine-western larch, western redcedar-western hemlock [116], Engelmann spruce-subalpine fir [86,116], boreal white and/or black spruce [132,133], and tamarack [133], as well as deciduous forests of quaking aspen and black cottonwood [106,133]. Island populations of American marten inhabit coastal forests of western hemlock, western redcedar, Alaska-cedar, Sitka spruce, lodgepole pine, and red alder (*Alnus rubra*) on the Queen Charlotte Islands [118] and western hemlock, Pacific silver fir, Douglas-fir, and western redcedar forests on Vancouver Island [6].

In the Northwest Territories and Yukon, American marten inhabit boreal forests dominated by several conifer species. In the western Northwest Territories, American marten occupy boreal forests dominated by black spruce, white spruce, jack pine, and tamarack; plant communities ranged in structure from open black spruce stands with little understory to closed-canopy mixed deciduous and coniferous stands [131]. Quaking aspen [115,155], paper birch [49], or willow [155] dominate some deciduous stands. In south-central Yukon, lodgepole pine dominate early seral areas, and subalpine fir and white spruce occur in mid- to late-successional areas [3].

| Major tree species of plant communities inhabited by American marten | |
|---|---|
| Overstory tree species | Location |
| Alaska-cedar | Alaska [83,118] |
| American beech | Maine [35,36,61,85,126,127,128,129,158], Ontario [62] |
| Balsam fir | Maine [35,36,61,85,90,126,127,128,158,188], Michigan [168], Wisconsin ([186], review by [69]), Alberta [138], Labrador [156], Manitoba [141,142], Newfoundland [50,51,59,80,157], Ontario [13,58,60,62,169,171] |
| Balsam poplar | Alaska [65,122,178], Ontario [1,169], Quebec [64], Yukon [155] |

| | |
|---|---|
| Basswood | Michigan [168], Wisconsin [63,186] |
| Bigtooth aspen | Maine [36], Ontario [62] |
| Black cottonwood | Alaska [148], Idaho [180], British Columbia [106,133] |
| Black spruce | Alaska [5,24,65,88,123,150,178], Maine [35,36,128,129], Michigan [168],Wisconsin [63,186], Alberta [138], British Columbia [132], Labrador [156], Manitoba [141], Newfoundland [50,51,59,80,157], Northwest Territories [49,115,131], Ontario [1,13,14,58,60,169,171], Quebec [135], Yukon [155] |
| California red fir | California [68,92,93,111,113,159,190] |
| Douglas-fir | California [92,190], Idaho [81,110,176,180], Montana [4,23],41,42,53, Oregon [16], Washington [94], Wyoming [39,81], British Columbia [6,52,116] |
| Eastern hemlock | Maine [35,36,129], Michigan [168], Wisconsin ([63,186], review by [69]), Ontario [58,60,62] |
| Eastern hophornbeam (*Ostrya virginiana*) | Ontario [60] |
| Eastern white pine | Maine [35,36,61,126,127,128,129], Michigan [168], Wisconsin [63,186], Newfoundland [59,80], Ontario [58,60,62] |
| Engelmann spruce | Colorado [7], Idaho [81,93,96,176,180], Montana [23,43,44,53,181], Washington [94], Utah [71,75], Wyoming [39,45,81,82,120,149,182], Alberta [138], British Columbia [52,86,106,116] |
| Grand fir | Idaho [176,180], Oregon [16] |
| Jack pine | Manitoba [141,142], Northwest Territories [115,131], Ontario [1,13,14,169], Quebec [135] |
| Jeffrey pine | California [92,93,111,113,159,190] |
| Limber pine | Wyoming [182] |
| Lodgepole pine | California [68,73,74,92,111,113,159,190], Idaho [81,93,96,110], Montana [4,23,43,44,53,57], Oregon [16,89,143], Utah [71,75], Washington [94], Wyoming [39,45,81,82,120,149,182], Alberta [138], British Columbia [106,116,118,132], Yukon [3,155] |
| Mountain hemlock | Alaska [8,83,148], California [74,159], Washington [117] |
| Northern red oak | Michigan [168], Wisconsin [63,186] |

| | |
|---|---|
| Northern whitecedar | Maine [35,36,128,129,158,187,188], Michigan [168], Wisconsin ([63,186], review by [69]), Ontario [13,169], Quebec [64] |
| Pacific silver fir | Washington [117,143], British Columbia [6] |
| Paper birch | Alaska [5,24,65,148,178], Idaho [180], Maine [35,36,61,85,90,126,127,128,129], Wisconsin [63,186], Labrador [156], Newfoundland [50,51,59,80,157], Northwest Territories [49], Ontario [1,13,58,60,169], Quebec [64,135] |
| Ponderosa pine | California [111], Idaho [110,180], Montana [23], Oregon [89], South Dakota [54] |
| Quaking aspen | Alaska [24,65,122,150,178], Colorado [7], Idaho [81,180], Maine [90], Wyoming [81,182], the Southwest [55], Alberta [138], British Columbia [106,132,133], Northwest Territories [115], Ontario [1,13,60,169,171], Quebec [64], Yukon [155] |
| Red alder | British Columbia [118] |
| Red maple | Maine [35,36,61,126,127,129], Michigan [168], Newfoundland [157], Ontario [60,62], Quebec [64] |
| Red pine | Wisconsin [63], Ontario [58,62] |
| Red spruce | Maine [35,36,61,90,126,127,128,129,158] |
| Redwood | California [153,154] |
| Sitka spruce | Alaska [8,9,83,118] |
| Speckled alder (*Alnus incana*subsp. *rugosa*) | Ontario [60] |
| Subalpine fir | Colorado [7], Idaho [81,93,96,176,180], Montana [23,43,44,53,181], Oregon [16], Utah [75], Washington [94], Utah [71], Wyoming [39,45,81,82,120,149,182], Alberta [138], British Columbia [52,86,106,116], Yukon [3,155] |
| Sugar maple | Maine [35,36,61,85,126,127,129,158], Michigan [168], Wisconsin [63,186], Ontario [58,60,62], Quebec [64] |
| Tamarack | Alaska [88,123,178], Maine [35,36,129], Wisconsin [63,186], British Columbia [133], Manitoba [141], Newfoundland [59,80], Northwest Territories [49,115,131], Ontario [169] |
| Western hemlock | Alaska [8,9,83,148], California [73], Idaho [176,180], |

| | |
|---|---|
| | Washington [117], British Columbia [6,52,116,118] |
| Western larch | Idaho [110,176,180], Montana [23,57,181], British Columbia [116] |
| Western redcedar | Idaho [176,180], Montana [57], British Columbia [6,52,116,118] |
| Western white pine | California [111], Idaho [176,180], Oregon [89] |
| Whitebark pine | California [74], Idaho [81], Montana [4], Wyoming [81] |
| White ash | Wisconsin [63,186] |
| White fir | California [92,93,111,153,159,190], Idaho [110] |
| White spruce | Alaska [5,8,24,65,122,148,150,178], Montana [23], Michigan [168], Alberta [138], British Columbia [106,132], Manitoba [141], Newfoundland [59,80], Northwest Territories [115,131], Ontario [13,58,60,62,169,171], Quebec [64], Yukon [3,155] |
| Yellow birch | Maine [35,36,61,126,127,128,129,158], Michigan [168], Ontario [58,60,62] |

**Plant community dynamics:** Fire is a major natural disturbance shaping plant communities across the range of the American marten, including plant communities in Alaska [24,65,150,178], California [111,159], Idaho [93,96], Montana [23,181], Washington [94], Wisconsin [63,186], British Columbia [6,106], Manitoba [140,141], Northwest Territories [131], Ontario [1], and Yukon [3,155]. Fire was not a major disturbance process on Chichagof Island, southeast Alaska [83] or in Newfoundland [80]. Insect outbreaks also play a major role in shaping plant communities across the range of the American marten. Large-scale insect outbreaks in areas occupied by American marten were reported in Alaska [8,148], Maine [35,36,85,126,128,129,187,188], Colorado [189], Newfoundland [50,80], and British Columbia (review by [145]).

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# BIOLOGICAL DATA AND HABITAT REQUIREMENTS

SPECIES: Martes americana

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- LIFE HISTORY
- DISEASES AND SOURCES OF MORTALITY
- PREFERRED HABITAT
- FOOD HABITS

LIFE HISTORY:

**Description:** The American marten is a long, slender-bodied weasel about the size of a mink with relatively large rounded ears, short limbs, and a bushy tail.

American marten in southwest Montana.
Photo by Nathan Stone.

American marten have a roughly triangular head and sharp nose. Their long, silky fur ranges in color from pale yellowish buff to tawny brown to almost black. Their head is usually lighter than the rest of their body, while the tail and legs are darker. American marten usually have a characteristic throat and chest bib ranging in color from pale straw to vivid orange (review by [38]). Sexual dimorphism is pronounced, with males averaging about 15% larger than females in length and as much as 65% larger in body weight (review by [38]). Body length ranges from 1.5 to 2.2 feet (0.5-0.7 m). Adult weight ranges from 1.1 to 3.1 pounds (0.5-1.4 kg) and varies by age and location. Other than size, sexes are similar in appearance (review by [28]).

American marten have limited body-fat reserves, experience high mass-specific heat loss, and have a limited fasting endurance. In winter, individuals may go into shallow torpor daily to reduce heat loss (review by [136]).

**Breeding:** American marten reach sexual maturity by 1 year of age, but effective breeding may not occur before 2 years of age (review by [136]). In captivity, 15-year-old females bred successfully (reviews by [38,166]). In the wild, 12-year-old females were reproductive [166].

Adult American marten are generally solitary except during the breeding season (review by [38]). They arepolygamous, and females may have multiple periods of heat (review by [166]). Females enter estrus in July or August (review by [136]), with courtship lasting about 15 days (review by [38]). Embryonic implantation is delayed until late winter, with active gestation lasting approximately a month. Females give birth in late March or April to a litter ranging from 1 to 5 kits (review by [136]). Annual reproductive output is low according to predictions based on body size. Fecundity varies by age and year and may be related to food abundance (review by [28]). In northeastern Oregon, low population reproductive rates were associated with high levels of predation on females prior to weaning kits [20].

**Denning behavior:** Females use dens to give birth and to shelter kits. Dens are classified as either natal dens, where parturition takes place, or maternal dens, where females move their kits after birth (review by [28]). American marten females use a variety of structures for natal and maternal denning, including the branches, cavities or broken tops of live trees [18,89,106,147,154,187,188], snags [18,37,76,89,147,154,182], stumps [6], logs [18,58,76,147,187,188], woody debris piles [6], witch's brooms [106], rock piles [18,32,58,147], and red squirrel (*Tamiasciurus hudsonicus*) nests or middens [18,147]. See Denning for more information on denning structures and habitats associated with denning.

Females prepare a natal den by lining a cavity with grass, moss, and leaves (review by ([165]). In southern Wyoming, females moved kits frequently to new maternal dens once kits were >13 weeks old [82]. In another study in southern Wyoming, the average number of maternal dens per individual was 10.8, ranging from 5 to 24 [147]. In northwestern Maine, females moved kits from tree-cavity natal dens to groundlevel log maternal dens when kits were 7 to 8 weeks old, then moved kits back into large tree dens when they gained coordination at 12 to15 weeks old [187,188]. In southern Wyoming, females did not move kits from aboveground to ground structures between natal and maternal denning; many natal dens were in ground structures [147].

In southern Wyoming, most females spent a majority of their time (>50%) attending dens in both preweaning and weaning periods, with less time spent at dens as kits aged. Females were often away from dens from dusk to midnight [82]. Paternal care has not been documented (review by [28]).

**Development and dispersal of young:** Weaning occurs at 42 days. Young emerge from dens at about 50 days but may be moved by their mother before this (review by [28]). In northwestern Maine, kits were active but poorly coordinated at 7 to 8 weeks, gaining coordination by 12 to15 weeks [187,188]. Young reach adult body weight around 3 months (review by [136]).

Kits generally stay in the company of their mother through the end of their first summer, and most disperse in the fall (review by [28]). The timing of juvenile dispersal is not consistent throughout American marten's distribution, ranging from early August to October (review by [28]). In south-central Yukon, young-of-the-year dispersed from mid-July to mid-September, coinciding with the onset of female estrus [3]. Observations from Oregon [19] and Yukon [3] suggest that juveniles may disperse in early spring. Of 9 juvenile American marten that dispersed in spring in northeastern Oregon, 3 dispersed a mean of 20.7 miles (33.3 km) (range: 17.4-26.8 miles (28.0-43.2 km)) and established home ranges outside of the study area. Three were killed after dispersing distances ranging from 5.3 to 14.6 miles (8.6-23.6 km), and 3 dispersed a mean of 5.0 miles (8.1 km) (range: 3.7-6.0 miles (6.0-9.6 km)) but returned and established home ranges in the area of their original capture. Spring dispersal ended between June and early August, after which individuals remained in the same area and established a home range [19].

**Daily activity patterns:** American marten activity patterns vary by region (review by ([165]), though in general, activity is greater in summer than in winter ([18], reviews by [38,136]). American marten may be active as much as 60% of the day in summer but as little as 16% of the day in winter (review by [136]). In north-central Ontario individuals were active about 10 to 16 hours a day in all seasons except late winter, when activity was reduced to about 5 hours a day [169,173]. In south-central Alaska, American marten were more active in autumn (66% active) than in late winter and early spring (43% active) [29]. In northeastern California, more time spent was spent traveling and hunting in summer than in winter, suggesting that reduced winter activity may be related to thermal and food stress or may be the result of larger prey consumption and consequent decrease in time spent foraging [190].

American marten may be nocturnal or diurnal. Variability in daily activity patterns has been linked to activity of major prey species ([190], review by ([165]), foraging efficiency [29], gender [30], reducing exposure to extreme temperatures ([29,178], review by [165]), season ([76,190], review by [136]), and timber harvest [169]. In northeastern California, activity in the snow-free season (May-December) was diurnal, while winter activity was largely nocturnal [190]. In Grand Teton National Park, American marten activity peaked at midnight and late morning in spring. In summer, activity peaked at midnight, early morning, and mid-afternoon [76]. In south-central Alaska, American marten were nocturnal in autumn, with strong individual variability in diel activity in late winter. Activity occurred throughout the day in late winter and early spring [29]. In western Newfoundland, American marten were more active at night than during the day in winter; this result contrasts with other studies but may be explained by the generally warmer temperatures of the study region [51].

**Daily and seasonal movement:** Daily distance traveled may vary by age [150], gender, habitat quality [169], season [76], prey availability, traveling conditions, weather, and physiological condition of the individual [110]. Year-round daily movements in Grand Teton National Park ranged from 0 to 2.83 miles (0-4.57 km), averaging 0.6 mile (0.9 km) ($n$=88) [76]. In Glacier National Park, Montana, year-round daily movements averaged 0.4 mile (0.6 km), ranging from 0.2 to 1.7 miles (0.1-2.8 km) [23]. One American marten in south-central Alaska repeatedly traveled 7 to 9 miles (11-14 km) overnight to move between 2 areas of home range focal activity [29]. Two individuals in southwestern Montana routinely moved >4 miles (7 km) overnight [43]. One individual in central Idaho moved as much as 9 miles (14 km) a day in winter, but movements were largely confined to a 1,280-acre (518 ha) [110] area. Juvenile American marten in east-central Alaska traveled significantly farther each day than adults ($x$=1.4 miles (2.2 km) vs. 0.9 mile (1.4 km); $P$=0.001) [150]. In north-central Ontario, daily linear distance traveled was greater for males than females and for adults in logged than in unlogged forest ($P$<0.0001) [169].

Studies from Wyoming suggest that immigration and emigration are most likely to occur in the fall [39,40,76], with males more likely to move more than females [40]. American marten may also make smaller seasonal movements. Several studies have documented a seasonal shift in home range [6,29,129] (see Home range for more information). Two studies have documented seasonal migration in elevation. In south-central Alaska individuals moved to higher elevations in spring and to lower elevations in autumn, which the author attributed to food availability [29]. At the Kenai National Wildlife Refuge, south-central Alaska, individuals moved to higher elevations during the snow season, likely seeking the increased thermal protection offered by deep snow [148].

**Population structure:** American marten populations may contain many transient individuals. Of 85 American marten captured in northwestern Montana, 35% were residents (present in study area for >3 months), 55% were transients (present for <1 week), and 9% were temporary residents (present for >1 week but <3 months) [78]. In Wyoming, less than half of the American marten observed in Grand Teton National Park were considered residents and 33% were considered transients. On the Bridger-Teton National Forest, Wyoming, 67% of the population was considered residents, 7% were temporary residents, and 26% were transients [39].

Population age structure depends heavily on whether or not a population is trapped. Age structure of trapped populations responds mostly to the timing and intensity of harvest (review by [28]). Age structure of populations may also fluctuate in response to prey availability (review by [136]). Over a 3-year study in east-central Alaska, age structure of a trapped population was 49% juvenile (<1 year old), 26% yearling (1-2 years old), and 25% adult (≥ 2 years old) [150].

**Population density:** Compared to other carnivores, American marten population density is low for their body size. One review reports population densities ranging from 0.4 to 2.5 individuals/km² [28]. Population density may vary annually [60,64] or seasonally [3]. It may be influenced by several factors. Low population densities have been associated with low abundance of prey species ([60,150], reviews by [28,136,165]), environmental stress (e.g., weather conditions) [150], logging ([126,128,158], reviews by [28,165]), and trapping pressure (114, review by ([165]).One study from southern Ontario found no detectible relationship between trapping mortality and changes in American marten density, though it did find some evidence of density-dependent population growth [60].

**Home range:** Home range size of the American marten is extremely variable, with differences attributable to sex [6,19,26,29,129,132,156,187,188], year [66], geographic area (review by [28]), prey availability ([19,66,80,150], review by [28,165]), cover type, quality or availability ([19,80,126,156,178], review by [28,165]), habitat fragmentation [80], reproductive status [90], resident status [23], predation [19], and population density (18,116, review by ([165]). Home range size does not appear to be related to body size for either sex [156]. Home range size ranged from 0.04 mile² (0.1 km²) in Maine to 6.1 miles² (15.7 km²) in Minnesota for males, and 0.04 mile² (0.1 km²) in Maine to 3.0 miles² (7.7 km²) in Wisconsin for females (review by ([165]). For a review of American marten home range size and variability throughout its range as of 1989, see Buskirk and Lyman [26]. For more recent home range information, see the following sources: Alaska [150], Idaho [176], Maine [129], Michigan [168], Montana [43], Oregon [19], Wisconsin [186], Wyoming [120], British Columbia [6,106,132], Labrador [156], Newfoundland [66], Quebec [64]. Home range estimates are difficult to compare between studies because of different techniques used to obtain locations and/or to calculate areas (review by ([165]).

Males generally exhibit larger home ranges than females [6,19,26,29,129,132,156,187,188], which some authors suggest is due to more specific habitat requirements of females (e.g., denning or prey requirements) that limit their ability to shift home range [129]. However, studies in east-central Alaska [150] and southeastern Quebec [64] did not find male home range to be larger than female. In both studies, 2 females exhibited unusually large home ranges; in one study both individuals were juvenile [150], and in the other study, much of the home range consisted of logged forest [64]. Males and females in northeastern California appeared to have approximately equal home range size [152].

Home range is generally larger in logged than unlogged areas [61,80,126,135,158,172], though all studies supporting this assertion are from New England or eastern Canada. In northern Maine, regenerating clearcuts (3-18 years old) comprised 16% to 50% of the home range of the adults studied [162]. In north-central Ontario, distances between core areas of individual home ranges were greater in logged (<5 to >30 years) than unlogged forest ($P<0.001$) [173]. In northeastern British Columbia, removal of immature forest cover of 17% of the study area resulted in home range shifts at the individual level but no detectable impact at the population level, though 5 American marten dispersed out of the treated area and 1 died [132]. In southeastern Quebec, most predictive models included an element of human or natural disturbance to explain increases in home range size; home ranges tended to be larger as road density increased or the landscape contained a higher proportion of unlogged stand with a light outbreak of eastern spruce budworm (*Choristoneura fumiferana*) [64].

In Wyoming, home range size varied with no apparent pattern relative to age, season, or year, including years with timber harvesting [120]. Similarly, home range sizes did not differ when comparing undisturbed to clearcut (100% removal) and selectively cut (40% removal)) habitat in Wyoming, though individuals may have shifted their home range in response to these disturbances [40].

Home ranges are indicated by scent-marking. American marten male pelts often show signs of scarring on the head and shoulders, suggesting intrasexual aggression that may be related to home range maintenance (review by ([165]). Home range overlap is generally minimal or nonexistent between adult males [3,23,29,30,40,76,186] but may occur between males and females [3,23,29,30,40,111], adult males and juveniles [29,148], and between females [30,40,178]. In northeastern Wisconsin a few individual male home ranges overlapped extensively (88% overlap) in winter [186]. In Grand Teton National Park, male home range overlap was small or nonexistent except in the fall [76]. On Vancouver Island, British Columbia, overlap within and between the sexes generally occurred at the periphery of home ranges [6].

Individual American marten tend to exhibit high fidelity to an established home range [19,29,120,129], though observations in Grand Teton National Park suggested that home range boundaries frequently shift [76]. In north-central Maine males tended to show more seasonal and year-round fidelity to home range than females, with some females exhibiting high home range fidelity while others abandoned or shifted home ranges seasonally [129]. In north-central Maine adult males shifted or expanded their home range when bordering males died [129]. In south-central Alaska, one male shifted home range completely, but most others showed small seasonal shifts in concentration areas within an established home range [29]. Seasonal shifts in home range were observed in Alaska [29] and Vancouver Island, British Columbia [6], but not at a different site in Alaska [148].

Observations from Alaska [29], California [113,152], Idaho [110], and Vancouver Island, British Columbia [6], suggest that American marten may concentrate activity within small parts of their home range. In Alaska [148] and on Vancouver Island [6], core use areas shifted seasonally. In northern California, individuals would occupy small areas of their home range for a few weeks, then completely shift activity to a new area [113]. In central Idaho, daily winter movements generally do not extend beyond a 1 mile$^2$ (260 ha$^2$) area, though throughout the winter an overall area 12 to 15 miles$^2$ (3,100-3,900 ha$^2$) was used [110].

Several authors have reported that home range boundaries appear to coincide with topographical or geographical features. In northeastern California, movements and home range boundaries were influenced by cover, topography (forest-meadow edges, open ridgetop, lakeshores), and other American marten [152]. In south-central Alaska, home range boundaries included creeks and a major river [29]. In an area burned 8 years previously in interior Alaska, home range boundaries coincided with transition areas between riparian and nonriparian habitats [178]. In northwestern Montana, home range boundaries appeared to coincide with the edge of large open meadows and burned areas; the authors suggested that open areas represent a "psychological rather than physical barrier" [78].

## DISEASES AND SOURCES OF MORTALITY:

**Diseases:** American marten host several internal and external parasites, including helminths, fleas (*Siphonaptera*), and ticks (*Ixodida*) (review by ([165]). American marten in central Ontario carried both toxoplasmosis and Aleutian disease, but neither affliction was suspected to cause significant mortality [166]. High American marten mortality in Newfoundland was caused by encephalitis [59].

**Sources of Mortality:** American marten are susceptible to predation and mortality from other natural causes. Trapping pressure causes high mortality in some areas.

Predators: American marten are vulnerable to predation from raptors and other carnivores. Some authors suggest that the threat of predation may be an important factor shaping American marten habitat preferences, a hypothesis inferred from their avoidance of open areas and from behavioral observations of the Eurasian pine marten (*Martes martes*) (review by [28]).

Specific predators vary by geographic region. In Newfoundland, red foxes (*Vulpes vulpes*) were the most frequent predator, though coyote (*Canis latrans*) and other American marten were also responsible for some deaths [80]. In deciduous forests in northeastern British Columbia, most predation was attributed to raptors [132]. Of 18 American marten killed by predators in northeastern Oregon, 8 were killed by bobcats (*Lynx rufus*), 4 by raptors, 4 by other American marten, and 2 by coyotes. Throughout the distribution of American marten, other predators include the great horned owl (*Bubo virginianus*), bald eagle (*Haliaeetus leucocephalus*), golden eagle (*Aquila chrysaetos*), Canada lynx (*L. canadensis*), mountain lion (*Puma concolor*) (reviews by [38,166]), fisher (*M. pennanti*) [139,142], wolverine (*Gulo gulo*), grizzly bear (*Ursus arctos horribilis*), American black bear (*U. americanus*), and gray wolf (*C. lupus*) [178]. In northeastern Oregon, most predation (67%) occurred between May and August, and no predation occurred between December and February [20].

Other sources of mortality: Trapping is a major source of mortality in some areas. In east-central Alaska, 72% of observed mortality was from trapping [150]. Of 28 deaths of known cause in western Quebec, 16 resulted from commercial trapping, and 12 were from natural causes including injury (6), predation (4), starvation (1), and disease (1) [135]. In Newfoundland, 75% of the human-caused mortality was incidental from snares set for snowshoe hares; the remaining 25% was from traps intended for American marten. Natural mortality accounted for 28% of American marten deaths [80]. American marten mortality may be biased towards certain segments of the population; in north-central Maine there was "substantial" predation mortality of transient females [85]. In Newfoundland trapping deaths were biased towards males and juveniles [80].

Other sources of mortality include drowning [168], starvation [59,80,168], exposure [20], choking, and infections associated with injury [80]. During live trapping, high mortality may occur if individuals become wet in cold weather (review by [38]). Several chemical contaminants (PCBs, DDT, mercury, chlordane, mirex, dierldrin) are carried by American marten, though there is no conclusive evidence of harmful effects (review by ([165]).

Survival rates: Survival rates vary by geographic region, exposure to trapping, habitat quality, and age. In an unharvested population in northeastern Oregon, the probability of survival of American marten ≥9 months old was 0.55 for 1 year, 0.37 for 2 years, 0.22 for 3 years, and 0.15 for 4 years. The mean annual probability of survival was 0.63 for 4 years [20]. In a harvested population in east-central Alaska, annual adult survival rates ranged from 0.51 to 0.83 over 3 years of study. Juvenile survival rates were lower, ranging from 0.26 to 0.50 [150]. In Newfoundland, annual adult survival was 0.83. Survival of juveniles from October to April was 0.76 in a protected population, but 0.51 in areas open to snaring and trapping [80]. In western Quebec, natural mortality rates were higher in clearcut areas than in unlogged areas [135].

Life span: American marten in captivity may live for 15 years. The oldest individual documented in a wild population was 14.5 years old (review by [28]).

## PREFERRED HABITAT:

Habitat characteristics preferred by American marten have been reviewed by several sources (e.g., [28,38,136,166]). Habitat quality for American marten is largely inferred from behavioral choices of individuals and indices of population density (review by [38]). Much of the information regarding American marten habitat is based on use of particular cover types compared to availability. As a measure of preference, this type of comparison assumes that individuals have equal access to available habitats and that time spent in a habitat translates into a fitness benefit, assumptions which may or may not be true (review by [27]).

American marten habitat preferences may vary by age ([23], reviews by [27,28]), sex ([186], review by [27]), residency [88,123], or season ([62,115], reviews by [27,28,136]). Measurement of habitat preferences may also vary with the scale of activity and method of analysis. Microhabitat selection includes preference for features at sites of specific use, such as resting, denning, or foraging. Stand selection includes preference for structural characteristics of stands, including snag density, tree size, or canopy closure. Home range or landscape selection includes preferences for habitat heterogeneity, interspersion, and juxtaposition. See the following studies for American marten habitat analyses at multiple scales: [62,81,92,106,116,133,134,153,176,180,182].

American marten are associated with many habitat features that are interrelated, including preferences for cover type, seral stage, structural complexity, moisture regime, landscape composition, and prey dynamics. In general, American marten occur mainly in forests and adjacent vegetation types. Late-successional stands of mesic coniferous forest, especially those with complex structure near the ground, are preferred (review by [28]). Forests with >30% canopy cover are considered optimal (review by [38]). Use of deciduous forest types is more common in the eastern part of the American marten distribution, where deciduous components are more typical of mature forests or some prey items are associated with early deciduous seres (review by [136]). Xeric forest types or those lacking complex physical structure are used little if at all. The preference for complex structure near the ground, particularly in winter, seems to be universal (review by [28]).

This section presents information on preferred habitat characteristics, including:

- **Plant community characteristics**
- **General cover requirements**
- **Habitat associations for specific life history activities**
- **Prey dynamics**
- **Predation and/or competition**
- **Elevation**
- **Climate**

**Plant community characteristics:** Characteristics associated with preferred plant communities include cover type, seral stage, moisture regime, use of riparian areas, and landscape characteristics. Use of burned areas has been documented in many studies.

Cover type: Studies from Maine [158,187], Michigan [168], British Columbia [116,132], Manitoba [139,141], Newfoundland [80], Ontario [58,167], Quebec [64], Yukon [155], and reviews [27,28,38,136,165] report a preference for coniferous forests, though it should be noted that deciduous forests are not widely available in many parts of the American marten's distribution. Also, some studies suggesting a preference for coniferous forests compare use of mature coniferous forest to use of regenerating deciduous forest, so it is not clear whether habitat preferences are related to cover type, seral stage, or both (review by ([62]). A variety of forest habitats, including young, deciduous forest, may be used if food and cover are available ([35,132,133], reviews by ([62,136,165]).

In general, American marten avoid cover types that lack overhead cover (e.g., prairies, herbaceous parklands or meadows, clearcuts, and tundra) ([53,73,74,176,187], reviews by [28,155]) due to an absence of preferred prey, structures for denning, concealment cover, escape cover, and/or access points to subnivean spaces (review by ([165]). Though they generally avoid open areas without overstory or shrub cover, American marten may occasionally travel along the edges of open areas or cross narrow open areas (review by [27]).

Use of nonforested habitats varies regionally, with open areas in some regions containing food and structure that open areas in other regions lack (review by [12]). Summer use of nonforested habitats above treeline is common in the montane part of American marten's distribution ([164], review by [28]). The type of nonforested habitat is important; open areas such as clearcuts, tornado blowdowns, or burned areas with large amounts of coarse woody debris may lack shrub or overstory cover but still provide adequate cover from tall herbs and debris, while protective cover in open grasslands, alpine zones, or other areas with short herbaceous vegetation may be lacking (review by [27]). Use of nonforested habitats may also be related to the proximity of and interspersion with closed-canopy cover types [159,176]. See General cover requirements for more information on this topic.

Seral stage: In general, American marten prefer late successional forests (e.g., see studies from California [92,93,153], Idaho [94,96,110,176,180], Maine [126,127,162,187], Oregon [21], Wyoming [30], Alberta [138], British Columbia [106,132], Newfoundland [50,66,157], Quebec [64], and Yukon [155]). The structural features important to American marten that develop with successional advancement include overhead cover, high volumes of large-diameter coarse woody debris, and small-scale horizontal heterogeneity of vegetation (review by [28]). American marten may use early-seral stands, particularly if complex physical structure is available ([6,35,62,88,116,123,132,186], review by [174]), stands contain attractions like seasonally abundant food items [110,162], or if mature stands are lacking across the landscape [6].

Moisture regime: Several studies indicate a preference for mesic over xeric sites, including studies in Colorado [7], Idaho [94,96], Montana [23,43,53], Oregon [21], Washington [117], British Columbia [106,116], and the Northwest Territories [115]. At temperate latitudes, mesic forests used by American marten are commonly riparian (review by [27]).

Riparian areas: Riparian areas contain habitat features important for American marten in many parts of their range [25,53,68,152,159,176,178]. They may provide large amounts of coarse woody debris [25,178] and/or high prey density [25], leading to enhanced foraging opportunities [152,176,178]. Riparian areas may also offer cool temperatures and access to water in summer [176]. In logged landscapes, riparian areas are often left uncut, providing structurally complex or mature forest [25,176].

In northeastern California, stream corridors were important for American marten movement and foraging [152]. In northern Idaho, individuals within a home range were located closer to streams than to random locations ($P<0.01$), and resting sites and travel routes were often located near riparian corridors [176]. In southeastern Wyoming, winter resting sites were closer to streams and lakes than expected ($P=0.007$) [25]. Below 6,725 feet (2,050 m) elevation in the northern Sierra Nevada, American marten strongly preferred riparian lodgepole pine plant associations ($P<0.05$). Riparian areas were used more for activity than resting, while adjacent mixed-conifer forests were used more for resting than activity. Riparian lodgepole pine forests with lush herbaceous cover were primary foraging areas [159]. In Grand

Teton National Park, one natal den was located in a cottonwood (*Populus* spp.) along the Snake River [37].

Riparian areas were key components of American marten home ranges in areas burned 8 years previously in interior Alaska. The home ranges of 10 American marten were centered in habitat around the Pitka Fork and Salmon rivers. Home range boundaries coincided with transition areas between riparian and nonriparian habitats. American marten clearly associated with riparian areas in daily activities. The author attributed this association to the large amounts of dead and down wood and vertical layering of log debris in riparian areas, and suggested that these habitat features offered both foraging opportunities and sufficient protective cover [178]. See Wildfire Case Study 1 for more information on this study.

Some studies suggest that riparian areas may constitute a barrier to movement or may shape home range boundaries. On the Kenai Peninsula, Alaska, individuals avoided ice-covered water ($P<0.001$) [8]. Very few tracks (3 of 251) were found on frozen lakes and rivers >50 feet (15 m) wide in southeastern Manitoba [139,141]. In south-central Alaska, home range boundaries included creeks and a major river [29]. However, some individuals do cross large rivers. Individuals in interior Alaska regularly swam across a river 154 feet (50 m) wide, sometimes more than once a day [109]. In southwestern Montana, at least one individual swam the Madison River [43]. In Yosemite National Park, California, individuals regularly crossed streams and traveled up to 330 feet (100 m) on frozen creek beds [74]. In interior Alaska, although home range boundaries were coincident with riparian areas, rivers presented no barrier to movement. Animals crossed rivers freely even in summer, sometimes more than once in 24 hours: "One marten was observed swimming the Pitka Fork, even diving under water for a short distance before emerging on the bank" [178].

Landscape characteristics: Plant community landscape metrics, including the juxtaposition and configuration of patches, may be important in American marten habitat selection [159,180]. However, one review suggests that the impacts of landscape features like fragmentation likely vary by geographic location [12], making broad inferences difficult.

Several studies suggest that landscape fragmentation has negative consequences for American marten ([75,80,81,116,180], review by [27]). Landscape metrics associated with fragmentation include patch size, edge indices, and habitat interspersion. Though highly fragmented forests may contain suitable patches of habitat for American marten, preferred habitats may be so separated by open areas that they are essentially unavailable (review by [27]) and/or predation risk is increased [180]. A few studies suggest that American marten favor large patches [34,92,168]. In an industrial forest in north-central Maine, forest patches used by American marten were 18 times larger than unused patches (median 67 acres (27 ha) vs. 3.7 acres (1.5 ha)) (*P*<0.003). Patches used by residents were closer to the nearest patch >6.7 acres (2.7 ha) (*P*=0.057) and to an adjacent forest preserve (*P*=0.075) than patches with no observed use [34]. On the Upper Peninsula of Michigan, American marten selected for large patches (*P*=0.05); 194 out of 232 locations were in conifer patches >345 acres (140 ha) [168].

American marten show no clear association with edge habitat, probably because of the variety of habitats studied and the inability of telemetry studies to detect fine-scale habitat preferences (review by [27]). Some studies suggest that interior forest areas are preferred [92]. American marten habitat use is negatively related to the proportion of the landscape in high-contrast edge habitat, like that between adjacent logged and unlogged forest [62,180]. However, edge indices were unrelated to American marten habitat use in an industrial forest in north-central Maine [34]. American marten in an experimental forest in southern British Columbia tended to use edges between forest and small forest openings (0.2-25 acres (0.1-10 ha)), avoiding forest farther from openings [86]. Several studies have documented American marten foraging in edge habitat between forested and open areas [29,76,77,86,152,159,181] (see Foraging).

Habitat interspersion was an important habitat feature of American marten habitat in the northern Sierra Nevada. American marten selected for tall, dense forest stands that were near meadows and that had many large snags, stumps, and logs (*P*<0.001). When active, individuals preferred to be within 200 feet (60 m) of a meadow and rarely used sites more than 1,300 feet (400 m) from meadows [159]. Some sources suggest that the mosaic of seral stages and cover types created by disturbances such as fire [88,94,96,109,123] and insect outbreaks [148] are important components of American marten habitat.

**General cover requirements:** American marten prefer habitat with complex physical structure ([35,44,64,81,106,127], reviews by [28,132]), which may be more important than plant community composition (review by [27]). Complex vertical and horizontal structure provides protection from predators, access to subnivean space for winter foraging, and protective thermal microenvironments, particularly in winter (reviews by [13,28]). Horizontal heterogeneity allows individuals to meet their needs in small areas, reducing travel distances (review by [28]). Components of complex physical structure positively associated with American marten habitat use include abundant and/or dense snags [13,21,106,126,127,147,159,176], downfall [44,111,186], logs [13,21,25,106,111,127,147,159,182], stumps [25,127,159,186], coarse woody debris [66,88,123,149], root tip-up mounds [186], shrubs [44,106], and live ground cover [44,111,159].

American marten habitat use has also been linked to relatively high tree basal area [44,62,111,126], tree diameter [13,21,176], tree height [13,126], and canopy closure [13,23,35,37,61,66,68,73,133,159]. Over 5 years of study in northeastern Oregon, 20 American marten showed a strong preference for forests with ≥50% canopy closure; based on availability, stands with 50% to 74% canopy closure were used more than expected while stands with <50% canopy closure were used less than expected ($P<0.01$) [21]. In Sequoia-Kings Canyon National Park, California, 72% of American marten detections were at sites with ≥40% canopy cover [68]. Some studies suggest that closed canopies are not required, at least not in all seasons. In central Maine, American marten used insect-defoliated stands with <50% canopy closure intensively from May to October. The author suggested that the vertical structure provided by large snags was a suitable substitute for live tree cover [126]. Several studies suggest that American marten avoid habitats lacking canopy closure, particularly in winter, to avoid predation. Few data are available to directly support this hypothesis, and it is also possible that American marten avoid open areas in winter because there is less available prey there (review by [27]).

Other habitat features that provide important cover for American marten include snow (see Importance of snow) and red squirrel middens. In the western part of American marten's range, activity is often associated with red squirrel middens, which provide important structures for natal and maternal denning [18,147] and resting [8,24,139,178], and are associated with traveling [8] and subnivean investigation [149]. In southern Wyoming, predictive models identified the number of red squirrel middens as the most important variable influencing maternal den site selection. Red squirrel middens were also an important variable in natal den site selection [147]. In south-central Alaska, 26 of 37 resting sites were associated with red squirrel middens, with heaviest use of midden resting sites occurring from early November to early April [24]. In Yellowstone National Park, Wyoming, 33% of subnivean access points were associated with red squirrel middens [149].

**Habitat associations for specific life history activities:**

- Resting
- Denning
- Traveling
- Foraging

Resting: American marten select rest sites based on their potential for thermal cover, protection from predators, and subnivean access in winter (review by [28]).

Rest site structures: American marten use a variety of structures for resting, including live tree platforms [18,23,53,154,176], canopies [8,63,162,182], or cavities

[18,23,53], snags [8,30,43,53,89,106,111,152,154,176], witch's broom structures resulting from dwarf mistletoe (*Arceuthobium* spp.) or fungal infection [18,23,30,37,125,182,187,188], red squirrel nests [23,24,43], red or Douglas's squirrel (*T. douglasii*) middens [8,24,53,139,143,178], logs [8,25,43,63,111,113,154,162,176,182], stumps [25,63,106,111,113,143,162], slash [18,30,53,63,89,143,152,154] or log [23,37,152] piles, tree root masses [30,37,58,63,89,106,139,143], shrubs [8,154], underground burrows [8,18,24,36,63,143,176], rock or boulder piles [25,37,43,53,58,63,143,154,176,182], roadside debris [143], and human structures [74,143]. Resting site structure varies by season, with higher use of arboreal structures in summer and groundlevel, subnivean structures in winter [18,23,36,37,63,111,162].

In northeastern Oregon, tree platforms were the most common resting site, and 77% of platforms were sheltered by 100% canopy cover. Type of resting site structure varied by tree species, with most platforms in Engelmann spruce and subalpine fir and most cavities in grand fir and western larch. Most hollow logs were also grand fir and western larch. Most (67%) of the cavity trees were dead. Rest site structure varied seasonally. In summer, most resting sites were tree platforms. In winter, most resting sites were located under the snow and were associated with horizontal structures, usually logs or slash piles. At least 75% of the subnivean resting sites had evidence of red squirrel middens. Use of cavities as resting sites peaked in April and from November to December [18].

Structures used as resting sites by American marten in northeastern Oregon over 5 years (adapted from [18])

| Structure | Percent of total resting sites (*n*=1,184) |
|---|---|
| Tree platform* | 43 |
| Tree cavity | 23 |
| Subnivean | 23 |
| Hollow log | 6 |
| Underground | 3 |
| Slash pile | 1 |

*Tree platforms include horizontal branches and/or structures associated with broom rust, dwarf mistletoe, or clumps of lichen (*Bryoria* spp.).

In northwestern Montana, DBH of live and dead trees used as resting sites for American marten ranged from 2 to 28 inches (5-71 cm). Total canopy cover ranged from 17% to 82% [23]. Data from northeastern Oregon also show that trees with a wide range of characteristics were used as resting sites [18].

Average tree characteristics (SD) of resting sites used by American marten in northeastern Oregon (adapted from [18])

| Characteristic | Tree platforms (*n*=517) | Tree cavity (*n*=271) | Hollow log (*n*=67) |
|---|---|---|---|
| Tree diameter (cm) | 51.7 (20.94) | 78.9 (21.22) | 66.1 (18.38) |
| Tree height/length (m) | 26.4 (7.85) | 21.2 (9.85) | 19.7 (10.68) |
| Resting site height (m) | 12.6 (5.99) | 11.2 (6.74) | NA |
| Canopy depth (%)* | 89.1 (18.62) | 52.4 (39.63) | NA |

*Canopy depth defined as the % of the bole that contained live or dead branches.

Selection of resting site structure may be influenced by availability. A study comparing resting sites in the eastern Cascade Range of central Oregon to the western Cascade Range of Washington reported that structures varied by study area, with slash piles used most often in Oregon and live trees used most often in Washington. Slash piles were 4 times more abundant in Oregon than in Washington [143].

American marten often reuse resting sites [24,25,37,53,111,113,162,182]. In southeastern Wyoming, subnivean resting sites with deep snow were likely to be reused, particularly when temperatures were low. One resting site was reused 19 times, and reused sites were sometimes reused by different individuals, though never concurrently [182]. In California, 10% of resting structures were reused up to 5 times [111], while spring resting structures in western Montana were used 1 to 6 times [53]. Males in northwestern Maine did not reuse summer tree canopy resting sites [187,188].

Habitat features at rest sites: One review reports that habitat features are inconsistent at resting sites [27]. In coastal northwestern California, summer and fall resting locations had high tree canopy closure (76%), dense shrub cover, and abundant dead woody structures. At the stand level, resting sites occurred in late-mature or old-growth stands, with old-growth stands used more than expected based on their availability

(*P*<0.0001). Selection for early-seral stands was either neutral or negative (*P*<0.0001) [154]. In northern Maine, summer rest site selection decreased with increasing canopy cover and understory foliage <1.5 feet (0.5 m). Increases in coniferous stems (<3.0 inches (7.6 cm) DBH) were associated with increased selection of winter resting sites, which the authors suggested offered subnivean access points and facilitated subnivean travel. The distribution of resting sites in coniferous, deciduous, or mixed forests did not vary seasonally, which may have been because structures for resting were abundant throughout the study area [36].

American marten resting sites have been associated with abundant dead wood [25,53,63,154,182] or snags [176], late-seral stage [24,63,154,182], mesic sites [53], riparian areas [25,143,154], or high overhead cover [24,73,143,154,159,182]. However, a preference for high canopy cover was not found at resting sites on the Kenai Peninsula [8] or in northern Maine [36]. Selection for aspect is not consistent across geographic areas, which may relate to local forest cover types associated with specific aspects; 74% of resting sites in northwestern California were on north aspects [154], while most in south-central Alaska were on southerly aspects [24]. Selection for specific local cover types was observed in northern Wisconsin [63], southeastern Wyoming [25,182], western Montana [53], and California [159], though preferences were often linked to the structural attributes occurring in the preferred cover type [25,53,182]. In interior Alaska, male American marten selected burned, open conifer-wet meadow and white spruce forest for resting in summer. Females were observed more often resting in unburned white spruce, black spruce, and mixed-wood (white spruce, paper birch, and balsam poplar) stands, but also rested in burned white spruce forest [178]. (See Wildfire Case Study 1 for more information on this study).

Two studies suggest that American marten avoid logged stands when choosing rest sites. Of 43 winter resting sites in industrial forests in northern Maine, 2 were in regenerating coniferous clearcuts, 18 were in uncut coniferous stands, 12 were in partially cut coniferous-deciduous stands, and 11 were along edges between clearcuts and residual stands. Of 27 summer resting sites, 5 were in regenerating coniferous clearcuts, 13 were in uncut coniferous stands, and 9 were in partially cut coniferous-deciduous stands [162]. In coastal northwestern California, most (65%) summer and fall resting sites were >330 feet (100 m) from logged areas (65%).

Denning: Denning sites provide protection from predators, inclement weather, and thermal stress (reviews by [18,28]).

Denning structures: American marten use a variety of structures for natal and maternal denning. Natal den structures include the cavities of live trees [18], snags [18,37,76,147,182], logs [18,76,147], stumps, woody debris piles [6], root wads [6,18], red squirrel middens [18], and rock piles [18,147]. In southern Wyoming, 3 natal dens were in snags averaging 26 inches (66 cm) DBH. In northeastern Oregon most tree cavity natal dens were in grand fir (84%), with 30% of the cavity trees alive. Trees averaged 33 inches (83 cm) DBH and were 75 feet (23 m) tall. Most of the hollow logs used as dens were grand fir, averaging 79 feet (24 m) long and 29 inches (73 cm) in diameter at the largest end. All logs had hollow chambers. Those chambers that could be measured averaged 8 to 10 inches (20-25 cm) in diameter inside. Underground natal dens were in rocky areas, under root wads, or under red squirrel middens. Natal dens were described as more secure than resting sites; they were dry, insulated, and inaccessible to predators other than other American marten [18]. In Grand Teton National Park, "nesting" sites were in hollow narrowleaf cottonwoods (*Populus angustifolia*) (7 standing and 1 fallen). The cavity at one nesting site was 33 feet (10 m) above the ground, and the entrance hole was 7 inches (18 cm) in diameter. Den height in standing trees ranged from 10 to 33 feet (3-10 m) above the ground. Mean DBH of 7 denning trees was 31 inches (79 cm) [76].

Maternal den structures include the branches, cavities or broken tops of live trees [89,106,147,154,187,188], snags [89,147,154], rock piles [32,58], logs [58,147,187,188], witch's brooms [106], and red squirrel nests or middens [147]. Five maternal dens in south-central Oregon were in large live or dead standing trees >29 inches (73 cm) DBH [89]. In northern Wisconsin, 6 of 7 maternal dens were in standing trees >20 inches (50 cm) DBH; no underground structures were used, and no association with coarse woody debris was found [63]. In northwestern Maine, 5 of 6 maternal dens were in hollow northern whitecedar logs or in mature northern whitecedar trees (DBH ranging from 20 to 30 inches (40-70 cm)); the remaining den was in a mature sugar maple [187,188]. In southern Wyoming, the mean diameter of 17 log maternal dens was 21 inches (53 cm), and 26 maternal dens were in snags averaging 22 inches (55 cm) DBH [147].

Structures (% of total) used as natal and maternal dens of female American marten in southern Wyoming. Adapted from [147].

| Structure | Natal dens (*n*=18) | Maternal dens (*n*=97) |
|---|---|---|
| Log | 6 | 18 |
| Snag | 17 | 27 |
| Live tree | 0 | 2 |
| Rock | 11 | 31 |
| Red squirrel nest | 0 | 4 |
| Artificial log* | 11 | 4 |

| | | |
|---|---|---|
| Red squirrel midden | 56 | 12 |
| Other** | 0 | 3 |
| *Logs from old cabins or slash piles.<br>**1 ground nest and 1 abandoned burrow of unknown origin. | | |

| Structures (% of total) used as natal and maternal denning sites by American marten in northeastern Oregon over 5 years (adapted from [18]) | | |
|---|---|---|
| Structure | Natal den (*n*=11) | Maternal den (*n*=19) |
| Tree cavity | 73 | 21 |
| Hollow log | 0 | 58 |
| Underground | 27 | 10 |
| Slash pile | 0 | 10 |

Use of denning structures may be influenced by availability. A study comparing denning sites in Oregon and Washington reported that structures varied by study area; females chose to den more often in coarse woody debris and slash in Oregon and in live trees and snags in Washington, which the authors attributed to availability. Trees used for denning were larger than what was generally available, with 90% and 76% of denning trees >20 inches (50 cm) DBH in Washington and Oregon, respectively [143].

| Structures used by American marten for maternal denning in Oregon and Washington (% of total in parentheses) [143] | | |
|---|---|---|
| Structure | Oregon | Washington |
| Live tree | 6 (19) | 14 (54) |
| Snag | 5 (16) | 8 (31) |
| Single log- bole | 10 (32) | 1 (4) |
| Logging slash | 9 (29) | 2 (8) |
| Rock | 0 | 1(4) |
| Animal burrow | 1 (3) | 0 |
| Total | 31 | 26 |

Denning habitat characteristics: Few studies describe in detail the habitat characteristics at American marten den sites, likely because few studies locate enough dens to make associations clear. In southern Wyoming, where researchers identified 18 natal dens and 97 maternity dens, structural characteristics associated with late-successional forests were important for den sites selected by females. For maternal dens, predictive models identified the number of red squirrel middens as the most important selection variable, followed by number of snags 10 to 15 inches (20-40 cm) DBH, number of snags ≥16 inches (41 cm) DBH, and number of hard logs ≥16 inches (41 cm) in diameter. For natal dens, number of middens, number of Engelmann spruce and subalpine fir >10 inches (20 cm) DBH, and number of hard logs ≥16 inches (41 cm) in diameter were the most important selection variables. Canopy cover was not significantly different at den sites compared to random sites, averaging 67.4% at natal dens, 58.2% at maternal dens, and 58.2% at random sites. The authors suggest that female American marten may be more selective in choosing natal dens than maternal dens, though this hypothesis was not tested [147]. On Vancouver Island, British Columbia, 7 natal dens were found in 30- to 40-year-old second-growth forest [6]. In the Northwest Territories, one female denned and produced young within an area burned 21 years previously [103].

Traveling: American marten travel to maintain territories, forage, and find resting sites (review by [27]). Though they can climb trees, American marten travel mostly on the ground. In winter, tracks in snow follow circuitous routes covering an individual's entire home range. Travel routes stay close to areas with overhead cover, with travel interrupted by frequent investigations where coarse woody debris penetrates the snow surface and provides subnivean access

American marten in Alaska.
Photo by Andy Baltensperger.

(review by [28]). In northeastern California, movements were variously influenced by cover and topography (e.g., forest-meadow edges, open ridgetop, lakeshores), and negatively influenced by the presence of other American marten [152].

In southeastern Ontario in the summer, American marten often used fallen logs as runways and appeared to select a travel route that allowed the fullest use of fallen logs [58]. In western Montana, individuals often made repeated use of the same trail [77]. In southwestern Montana logging roads, snowmobile trails, paved highways, and small streams did not impede movement; at least one individual swam the Madison River [43]. In northern Idaho, hiking trails and skid roads were used as travel routes [176].

In general, American marten avoid openings while traveling. In central British Columbia most individuals avoided traveling through xeric cover types, early-seral forests, lakes, or wetlands [106]. However, American marten may use the ecotone between open areas and forests while traveling [23]. If individuals travel through an open area, they may use scattered trees as cover [73,74] or travel in a more direct pattern [8,158]. Open areas that American marten have crossed while traveling include alpine areas, 25-year-old burned areas [155], frozen aquatic areas [53,155], sparse forests [8,155], open sagebrush-grassland [53], meadows [73,74,94,96], and regenerating clearcuts [158].

Travel patterns from 3 areas of the American marten's range are described below.

On the Kenai Peninsula, American marten traveling in winter selected snow and cover types largely in proportion to type availability at the home range scale. At the forest patch scale, movement paths were more winding or twisting through dense forest types compared to open forest types ($P<0.001$). These movement patterns suggest that individuals were responding to the denser canopy cover, elevated levels of coarse woody debris, and higher density of red squirrel middens present in dense forest types compared to other available vegetation types. Movement patterns may also reflect more foraging opportunities because individuals stop to investigate subnivean access points near coarse woody debris. Travel routes through open or ice-covered areas were significantly more straight than travel routes in vegetated areas ($P<0.001$) [8].

In Yosemite National Park, winter travel routes occurred in all cover types with no detectible preferences. Topographical features did not restrict travel; streams were crossed repeatedly and rock domes were climbed, though often with the aid of scattered tree cover. Individuals traveled across meadows ≤160 feet (50 m) wide but did not rest or hunt in them. Meadows >160 feet (50 m) wide were crossed using scattered tree cover; the longest open distance crossed was 440 feet (135 m). Individuals also skirted meadows by traveling along the ecotone between meadow and lodgepole pine forest. Microhabitat structure varied between travel routes and random points; travel routes had lower branch height, greater overhead cover, and shorter distance to nearest tree than random points ($P<0.01$). While moving, individuals preferred areas with 100% overhead cover ($P<0.01$), but they did not show a preference for dense forest stands. Instead, cover was selected by using a zigzag travel pattern that moved from tree to tree; two-thirds of all travel points were <7 feet (2 m) from a tree. Travel paths were also frequently adjusted to investigate the tracks of other animals [73,74].

In heavily logged forests in western Newfoundland, 74% of American marten winter trails were in forested cover types. The other 26% of tracks were in regenerating clearcuts, even though clearcuts represented 41% of the study area. Sixteen- to 23-year-old clearcuts with balsam fir regeneration >7 feet (2 m) high were not used at all. American marten showed no preference for residual stands >60 acre (25 ha) or undisturbed forest. They demonstrated a strong preference for small residual stands (<60 acre (25 ha)); while small residual stands comprised only 4.2% of the study area, 32.4% of travel routes were in this cover type. Travel patterns varied by cover type; travel routes through clearcuts were generally in a straight line, moving from one residual stand to another. Travel routes in forested habitats often exhibited a zigzag and looped pattern. While traveling, individuals crossed openings 70 to 1,970 feet (20-600 m) wide (87% of crossings were <820 feet (250 m)), though only 21% of pauses occurred in nonforested cover types. Pauses in all cover types were often associated with trees, sticks, or slash protruding above the snowpack or with the tracks of prey species such as the snowshoe hare and red squirrel [157].

Foraging: American marten foraging is often associated with woody debris [1,23,30,45,76,133,139,148,149,178], clumps of small trees [45,76,110,139], or the bases of large trees [139,148], because these structure often offer subnivean access [1,23,30,45,76,139,142,148,149,178] or are preferred microhabitats of favored prey species [1,40,110,149]. Subnivean hunting may be more common than surface hunting in winter [30,37,76]. In Grand Teton National Park, evidence of successful above-snow hunting was limited to one observation; 77% of 75 foraging investigations involved American marten descending to subnivean levels, with access typically gained via a cavity in a the snow formed below a partially fallen tree [37].

In southeastern Manitoba, foraging individuals often stopped or circled the roots of fallen trees, logs, coverts of young conifers, or the snow-laden branches of larger trees. American marten stopped 2.2 times/km, dug holes in the snow cover 1.0 time/km, and climbed 1 tree/10 km of trail while foraging [139,142]. In Wyoming, prey were frequently captured in association with large (diameter >15 inches (38 cm)) dead, fallen trees protruding out of the snow. American marten would follow downed trees below the snow's surface to extensive snow-free galleries formed by snow-covered vegetation and fallen trees near ground level [40].

In western Montana, American marten traveled a zigzag course that covered all down logs and windfalls in a large area and ultimately covered "every inch of an area one-tenth to one-fifth acre in size." In areas without downed logs, such as small openings and brushy swamps, individuals tunneled and dug through the snow every few inches [77]. In northeastern California, foraging American marten followed well-traveled routes that appeared to be nonrandom. Their travel pattern while hunting was a weaving or zigzag pattern that investigated all structures (e.g., logs, stumps, tree bases) within a given area [152]. In Grand Teton National Park, most investigation sites (83%) were below the snow surface, and 75% of the investigations were in areas that had >25% canopy cover. Subnivean investigations were usually under forest cover (89% of observations), with the rest occurring in an ecotone between forest and meadow. Entry below the snow surface was usually via a cavity in the snow formed by a fallen tree or sapling. Most sites (88.4%) were associated with fallen trees or saplings, and movement under the snow appeared to be within a network of fallen trees [76].

Several studies report that American marten prefer to hunt in areas with canopy cover and avoid hunting in open areas lacking cover [30,53,73,74,86,94,96,152,159]. In the northern Sierra Nevada, American marten preferred stands with 40% to 60% canopy closure at foraging sites and avoided stands with <30% canopy closure [159]. In Grand Teton National Park, mean canopy cover at foraging sites was 28.9%, with 75% of foraging investigations in areas that had >25% canopy cover [76]. Foraging in open areas has been documented in some areas. In western Montana, American marten hunted in small grassy openings within the forest [181]. In southeastern Manitoba, American marten sometimes hunted in moderately open black spruce-tamarack bogs up to 650 feet (200 m) wide in winter [139,142]. American marten use of open areas is often associated with a specific food resource or with adequate cover nearby. Vernam [178] suggested that American marten may use open areas regenerating after fire to forage on abundant summer berry crops. In northeastern

California, logged areas were avoided in winter but used for foraging in summer if they were adjacent to dense stands of intact forest, contained slash, and had some canopy cover [152]. In logged areas in northern Maine, hunting activity was associated with uncut and partially cut stands and not with regenerating clearcuts [162].

Several studies suggest that American marten forage in edge habitat between forested and open areas [29,76,77,86,152,159,181]. In Montana, American marten foraged along edges between regenerating and mature lodgepole pine forest [77] and between large grassy meadows and forest [181]. In Grand Teton National Park, 11% of subnivean foraging investigations occurred in an ecotone between forest and meadow [76]. In southern British Columbia, American marten activity was concentrated in forests adjacent to openings creating by logging [86]. In south-central Alaska, American marten foraged in black spruce woodlands, particularly where this cover type interfaced with other forest types and sedge (*Carex* spp.) meadows [29]. In the northern Sierra Nevada, American marten hunted primarily beneath dense forest canopy near meadow edges or in riparian lodgepole pine forests with lush herbaceous cover [159].

Not all reports indicate that edges provide suitable foraging habitat for American marten. Winter travel patterns of foraging American marten in Idaho and Wyoming were more linear along edges between intact forest and clearcuts than in the forest interior, suggesting that edge habitat did not provide suitable foraging opportunities in the study areas [81].

Other features associated with American marten foraging include riparian areas [23,86,152,159,178], squirrel middens [149,159], and garbage dumps [152]. American marten in central British Columbia avoided wetlands and cover types that were xeric or in young seral stages while foraging in winter [106].

**Prey dynamics:** Though some sources relate American marten habitat preference to the habitat preferences of prey species, it is not clear whether American marten prefer habitats occupied by prey that is easy to catch or if the habitat contains physical structures that render prey more vulnerable. American marten do not consistently select habitat where prey is more abundant (review by [27]), though higher prey numbers and American marten habitat use have been linked in studies from Maine [61], Ontario [58,62,169], Manitoba [139,141], Wyoming [40,149], Montana [23,44], Idaho [110,176], Northwest Territories [49], and British Columbia [106]. In some areas, American marten use of what would seem to be unsuitable habitat (e.g., early-seral [106], open, or burned [94,96] cover types) was explained by regionally or seasonally abundant prey items in these cover types.

**Predation and/or competition:** Potential predation by or competition with sympatric fishers may influence American marten habitat selection or use ([98,99,139,168], review by [28]). See Importance of snow for more information on this topic. Some authors suggest that the threat of predation may be an important factor shaping American marten habitat preferences, a hypothesis inferred from their avoidance of open areas and from behavioral observations of the Eurasian pine marten (review by [28]).

**Elevation:** American marten occur in a wide range of elevations throughout their distribution.

| Elevation at sites occupied by American marten | |
|---|---|
| Location | Elevation (feet) |
| Alaska | 400 to 1,201 [109] |
| California | 8,596 to 11,073 [73] |
| Colorado | 7,874 to 14,255 [7] |
| Maine | 1,085 to 2,410 [129] |
| Montana | 6,400 to 8,200 [44] |
| Oregon | 5,495 |
| Washington | 2,500 to 6,000 [143] |
| Wyoming | 6,444 to 13,730 [39] |
| British Columbia | 2,380 to 2,690 [132] |
| Newfoundland | 260 to 2,300 [51] |

**Climate:** In general, American marten inhabit areas with northern, continental climates receiving low mean annual temperatures and substantial winter snow, like the climate of Maine [129], Wyoming [39], or Ontario. Average minimum temperature in Ontario in January is -13 °F (-25 °C); average maximum temperature in July is 77 °F (25 °C). Snow accumulates to 30 to 35 inches (75-90 cm) from early November to about March, melting by mid-May [171]. American marten also inhabit areas with maritime climates that experience heavy rainfall and sporadic snowfall, including Chichagof Island, southeastern Alaska [9], coastal northwestern California [154], and the Queen Charlotte Islands, British Columbia [118]. Transition zones between maritime and continental climate occur at the Kenai National Wildlife Refuge in south-central Alaska [148].

Weather may impact American marten activity, resting site use, and prey availability. One review notes that individuals may become inactive during storms or extreme cold [165]. In Yosemite National Park, American marten were generally inactive during "severe" storms [74]. In interior Alaska, a decrease in above-the-snow activity occurred when ambient temperatures fell below -4 °F (-20 °C) [178]. In southeastern Wyoming, temperature influenced resting site location. Above-snow sites were used during the warmest weather, while subnivean sites were used during the coldest weather [25,182], particularly when temperatures were low and winds were high following storms [182]. High mortality may occur if American marten become wet in cold weather, as when unusual winter rains occur during live trapping (review by [38]). In southeastern Wyoming, temperature was linked to resting site use; above-snow sites were used during the warmest weather, while subnivean sites were used during the coldest weather ($P$=0.007) [25]. In Yosemite National Park, drought conditions increased the diversity of prey items; American marten consumed fish and small mammal species made more accessible by low snow conditions in a drought year [74].

Importance of snow: Snow is an important habitat feature in many parts of the range of the American marten, providing thermal protection [8,148] and opportunities for foraging and resting [30,37,45,76]. American marten may travel extensively under the snowpack. Subnivean travel routes of >98 feet (30 m) were documented in northeastern Oregon [168], >33 feet (10 m) on the Upper Peninsula of Michigan [168], and up to 66 feet (20 m) in Wyoming [76].

American marten are well adapted to snow. On the Kenai Peninsula, individuals navigated through deep snow regardless of depth, with tracks rarely sinking >2 inches (5 cm) into the snowpack [8]. Researchers on the Kenai Peninsula suggested that snowfall pattern was the most limiting factor to American marten distribution, with American marten presence linked to areas with deep snow [8,148].

Adaptations to deep snow are particularly important in areas where the American marten is sympatric with the fisher, which may compete with and/or prey on American marten. In southeastern Manitoba, one study reported that American marten were less hindered by soft snow cover than fishers [139,141]. In California, American marten were closely associated with areas of deep snow (>9 inches (23 cm)/winter month), while fishers were more associated with shallow snow (<5 inches (13 cm)/winter month). Overlap zones were areas with intermediate snow levels [99]. In Maine, American marten were only common in northern parts of the state, which had frequent, deep snowfalls. They were not common in southern Maine, where snowfall was less and fishers were more abundant. Age and recruitment ratios suggested that there were few reproductive American marten where snow was shallow and few reproductive fishers where snow was deep [98].

Where deep snow accumulates, American marten prefer cover types that prevent snow from packing hard and have structures near the ground that provide access to subnivean sites (review by [27]). While American marten select habitats with deep snow, they may concentrate activity in patches with relatively shallow snow. In north-central Idaho, American marten activity was highest in areas where snow depths were <12 inches (30 cm); the authors suggested that shallow snow allowed for easier burrowing for food and more shrub and log cover [94,96]. In southeastern Ontario, winter snow tracks indicated that activity was concentrated in conifer forests, where snow was shallower relative to other sites and red-backed voles were most abundant [58].

## FOOD HABITS:

American marten are opportunistic predators, influenced by local and seasonal abundance and availability of potential prey (review by [136]). They require about 80 kcal/day while at rest, the equivalent of about 3 voles (*Microtus*, *Myodes*, and *Phenacomys* spp.) (review by ([165]). Voles dominate diets throughout the American marten's geographic range (review by [136]), though larger prey—particularly snowshoe hares [42,139,142]—may be important, particularly in winter [61,148]. Red-backed voles (*Myodes* spp.) are generally taken in proportion to their availability, while meadow voles (*Microtus* spp.) are taken in excess of their availability in most areas. Deer mice (*Peromyscus maniculatus*) and shrews (*Soricidae*) are generally eaten less than expected, but may be important food items in areas lacking alternative prey species (review by [28]). Birds were the most important prey item in terms of frequency and volume on the Queen Charlotte Islands, British Columbia [118]. Fish may be important in coastal areas [9,118]. See Martin [112] for a review of American marten feeding ecology, including a summary of 22 studies on food use. For additional information on specific food items consumed by American marten, see the following sources: Alaska [9,29,88,109,123], Maine [61,158], Wyoming [30,76], Montana [181], Idaho [94,96,110], California [74,111,152,190], Oregon [16], Labrador [151], Northwest Territories [49,115,131], Ontario [42,58,169,171], Manitoba [139,142], and British Columbia [6,118].

Habitat preferences of dominant prey items are extremely variable. Red-backed voles prefer coniferous forests, where they are associated with large-diameter logs and understory cover. Meadow voles (*Microtus* spp.) occupy herbaceous and shrubby meadows. Red and Douglas's squirrels are largely restricted to coniferous forests in cone-producing stages, especially late-successional stages, though red squirrels may occur in deciduous forests in the eastern United States. Snowshoe hares generally prefer dense coniferous forest, dense early-seral shrubs, and swamps. Yellow-cheeked voles, important prey in Alaska, are variously reported to have wide habitat tolerances, be restricted to postfire seres, or be associated with lightly burned forest (review by [28]). Population dynamics of prey species may influence prey selection [9,131,151,169]. For more information on habitat associations of potential American marten prey, see the following FEIS reviews: snowshoe hare, red squirrel, northern red-backed vole,meadow vole, and deer mouse.

American marten diet may shift seasonally [6,16,29,58,96,111,115,148,152,181,190] or annually [29,74,115,131,151]. In general, diet is more diverse in summer than winter, with summer diets containing more fruit, other vegetation, and insects. Diet is generally more diverse in the eastern and southern parts of American marten's distribution compared to the western part (review by [136]), though there is high diversity in the Pacific states. American marten exhibit the least diet diversity in the subarctic, though diversity may also be low in areas where the diet is dominated by large prey species (e.g., snowshoe hares or red squirrels) (review by [112]).

American marten may be important seed dispersers; seeds generally pass through the animal intact, and seeds are likely germinable [183]. One study from Chichagof Island, southeast Alaska, found that Alaska blueberry (*Vaccinium alaskensis*) and ovalleaf huckleberry (*V. ovalifolium*) seeds had higher germination rates after passing through the gut of American marten compared to seeds that dropped from the parent plant. Analyses of American marten movement and seed passage rates suggested that American marten could disperse seeds long distances; 54% of the distances analyzed were >0.3 mile (0.5 km) [83].

FEDERAL LEGAL STATUS:
Not listed [177]

OTHER STATUS:
This species, and several subspecies of American marten, have state and provincial legal status. Information on state- and province-level protection status of animals in the United States and Canada is available at NatureServe, though recent changes in status may not be included.

MANAGEMENT CONSIDERATIONS:
Several life history characteristics inhibit American marten population recovery from natural and human-caused population declines. American marten have large spatial requirements for their body size, low population densities, and low reproductive rates

(review by [28]). Small litter size and delayed maturity make it difficult for populations to recover from large losses ([76], review by [28]). Several populations in the western United States are known or suspected to be geographically isolated, suggesting they may be more vulnerable to negative consequences of human activities (review by [28]).

American marten populations may be negatively impacted by several anthropogenic and natural disturbances, including habitat loss, timber harvest, trapping, climate change, and insect outbreaks. For a review of the impact of human activities (e.g., trapping, logging, agriculture) on American marten and other mustelids in North America, see Proulx [137].

**Habitat loss:** Habitat loss due to both anthropogenic and natural disturbance is cited as a major factor in the decline and/or extirpation of some American marten populations (reviews by [10,28,136,168,185,191]). Population fluctuations in the Northeast are largely attributed to changes in forest cover due to logging and subsequent reforestation. Major population declines in California are likely the result of loss of mature forest due to timber harvest (review by [28]).

**Timber harvest:** Timber harvest is common throughout the range of the American marten. In general, it has a negative effect on American marten; timber harvest removes overhead cover and large-diameter coarse woody debris, and in the case of clearcutting, may convert mesic sites to xeric sites (review by [28]). The structural changes associated with logging reduce protective cover [30] and may also alter the abundance and distribution of prey species ([30,40,61,71,75,169,173], reviews by [28,97]). In north-central Ontario, American marten in uncut areas encountered 2 to 3 times as many prey items and killed up to 119% more prey biomass compared to areas cut anywhere from <5 to >30 years previously ($P$=0.003) [169,173].

Timber harvest may lead to lower American marten densities [1,30,126,158], larger home ranges [135,158], home range shifts [132], higher natural mortality [135], higher dispersal rates [132,135], greater daily movements, greater distances between core use areas within a home range, and shifts in daily activity patterns [173]. American marten avoided harvested areas in Maine [61,126,127], Wyoming [40,81], Montana [43,53], Idaho [81], Utah [71,75], Oregon [21], California [152,153], Newfoundland [59,157], Quebec [64], Ontario [170], Alberta [138], and British Columbia [86].

In general, American marten make little or no use of clearcuts for several decades following harvest (review by [28]). In Idaho and Wyoming, the clearcuts crossed by American marten were significantly narrower than clearcuts they did not cross (464.2 feet (141.5 m) vs.1,053.5 feet (321.1 m), $P$<0.001); crossed clearcuts also contained abundant aboveground structures (e.g., standing trees, snags) [81]. Use of harvested areas may be higher where partial or selective harvest methods are used instead of clearcutting ([30,40,61,62,64,158,162], review by [97]); postharvest silvicultural treatments are used [170]; harvested stands are close to intact forest [72,152]; treatments are small ([86], review by [97]); forest regeneration is relatively fast [116,127]; or harvested areas offer benefits like seasonal food items [152,162]. Use of harvested areas may be greater as time since treatment increases [43,61,138].

See the following sources for management recommendations related to timber harvest and American marten habitat: [11,36,72,75,105,127,174].

**Trapping:** American marten are trapped for their fur in all but a few states and provinces where they occur (review by [136]). In North America, the highest peak trapping year occurred in 1820, when approximately 272,000 American marten were harvested (review by ([165]).

Harvest is a major source of American marten mortality in trapped populations ([135,150] review by [28]) and may account for up to 90% of all deaths in some areas (review by [28]). Overharvesting has contributed to local extirpations [10,168]. Trapping may impact population density, sex ratios ([126], review by ([165]) and age structure (reviews by [28,136]). Several studies suggest that juveniles are more vulnerable to trapping than adults ([4,43,80], review by [10]), and males are more vulnerable than females ([43,80], reviews by [28,189]). American marten are particularly vulnerable to high levels of trapping mortality in industrial forests (review by [136]).

See the following sources for information related to trapping and its impact on American marten populations: Alaska [150,161], Maine [85,90,126,128], Montana [43], Newfoundland [80], Ontario [60], Quebec [135], Yukon [3]. See the following sources for management suggestions related to harvest: [28,137,165,189].

**Climate change:** Climate change has the potential to significantly impact American marten populations through changes in vegetation, snowpack depth, and climate-related disturbance.

One model simulation investigated the potential impacts of climate change on American marten populations isolated from boreal populations at the southern extension of their range in southeastern Canada and the northeastern United States. The author hypothesized that decreased snowfall resulting from climate change may reduce American marten populations through decreased prey availability and decreased competitive advantage over sympatric carnivores. In modeling exercises correlating regional American marten distribution with vegetation and snowfall, American marten populations experienced greater declines due to climate change (modeled as decreased snowfall; 40% population decline) than to trapping pressure (30% population decline) or logging (16% population decline). Climate change and logging interacted to cause greater predicted decreases in American marten populations (61% population decline). Vulnerability to population decreases and fragmentation varied within the study region, with greater predicted impacts in areas with smaller, isolated, and/or peripheral populations [32].

Climate change may also impact related disturbances (e.g., fire and insect outbreaks) that effect large areas of the landscape; modeling suggests the potential for American marten to decline following large-scale mountain pine beetle (*Dendroctonus ponderosae*) outbreaks, which may increase with climate change [163]. On the Kenai Peninsula, managers were concerned that climate change could degrade habitat preferred by local American marten populations, including mature forests with closed canopies, complex structure, and a consistent, deep snowpack. As of 2009, the region had already experienced major shifts in landcover composition attributed to climate change, including increased spruce beetle (*D. rufipennis*) outbreaks, shifting fire regimes, rising treelines, drying wetlands, and increasing accumulated yearly snow depths. Spruce beetle outbreaks reduced overhead canopy cover and could potentially convert white spruce forest to early-successional hardwood forests. The author suggests that climate change may be responsible for recent shifts in American marten distribution in the region and that future American marten habitat could be limited by large-scale landscape changes resulting from increasing fire frequency and insect outbreaks. "Because of their physiological sensitivity to environmental conditions, American marten represent one of the most proximate, mammalian sentinel species of climate change" [8]. Concern over the impact of vegetational shifts on American marten is also reported from California [92] and the Greater Yellowstone Ecosystem [146]. Changes in snowpack dynamics are also a concern, because lower snowpacks in some areas could decrease the American marten's competitive advantage over fishers [92,99].

**Insect outbreaks:** Insect outbreaks are a common disturbance process in parts of the range of the American marten. Studies associating American marten with insect outbreaks include reports from Alaska [8,148], Colorado [189], Maine [35,126,187,188], British Columbia [145], and Newfoundland [50]. Insect outbreaks may result in widespread mortality of canopy trees, which in turn leads to more open canopies [35,145,148] and more snags [126,145,148], logs [126,145,148], root masses [126], and shrubs [145,148]. Prey species composition or abundance ([8,189], review by [145]) may also change. It is not clear whether changes resulting from insect outbreaks benefit or harm American marten. Impacts from mountain pine beetle infestations in lodgepole pine forests in British Columbia were predicted to change over time. Short-term impacts (initial infestation to understory recovery in 1-5 years) include reduced security from avian predators and a change in prey type and abundance. Medium-term impacts (20-50 years) include a decline in the abundance of snags and an increase in coarse woody debris, resulting in fewer tree cavities but more structures for ground dens. Longer-term impacts (70-100 years) include the decay of coarse woody debris, which may reduce den sites and limit subnivean access (review by [145]).

On the Kenai Peninsula, biologists suggested that the impacts of beetle outbreaks would not necessarily be negative; impacts might be similar to those of selective harvesting. The landscape following insect outbreaks might be a mixture of islands of dense trees and open areas filling in with dense shrubs, with abundant snags and downed logs [148]. However, a study in the same region found that American marten were infrequently detected in white spruce forests impacted by spruce beetles, and were twice as likely to be located outside of beetle-damaged areas, despite the abundance of coarse woody debris and snags found in beetle-damaged areas. The author suggested that the low canopy cover in beetle-killed forest did not meet protective needs, and establishing reedgrasses (*Calamagrostis* spp.) may have reduced habitat for potential small mammal prey [8].

Stands suffering heavy mortality following insect outbreaks may have more complex horizontal and vertical structure than those impacted by logging [50,126] or fire [189]. In central Maine, stands defoliated by eastern spruce budworm were used by American marten, while regenerating clearcuts were not (both were in postdisturbance years 10-20). Stands defoliated by eastern spruce budworm had more snags, downed logs, roots masses, and taller trees compared to regenerating clearcuts. Insect-defoliated stands with <50% canopy closure were intensively used, suggesting that vertical structure provided by large snags can substitute for live trees and that closed-canopy conditions are not required [126]. In north-central Maine, American marten used stands with substantial (<50% canopy closure) eastern spruce budworm mortality significantly more than mature, mixed coniferous-deciduous forest in summer ($P=0.003$) [35]. In western Newfoundland mature and defoliated conifer stands were used more than expected ($P<0.004$), while open and early-seral (regenerating) stands had low use [50].

American marten may also be impacted by forest management activities associated with insect outbreaks, including salvage harvest (149, review by [145]), road building, and postharvest site treatment, which may remove large stands of dead canopy trees, create large openings, fragment the landscape, and damage developing understory vegetation and coarse woody debris (review by [145]).

# FIRE EFFECTS AND MANAGEMENT

SPECIES: Martes americana

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DIRECT FIRE EFFECTS:
The direct effects of fire on American marten are likely minimal. Reviews suggest that medium to large mammals are typically mobile enough to avoid fire, though mortality may result from large, fast-moving fires [108,114,130]. Biologists in southeastern Manitoba documented a juvenile American marten male and a juvenile female surviving a 160,000-acre (65,000 ha) mixed-severity wildfire in May. Neither animal appeared to be burned by the fire [139]. Following an extensive but low-severity fire in central Alaska, a trapper observed American marten tracks amid smoldering ground after early autumn snowfalls [88].

Because American marten kits are largely immobile until approximately 12 to15 weeks old [187,188] and both ground and arboreal denning structures may be destroyed by fire, kits may be vulnerable to mortality during spring fires (review by [68]).

INDIRECT FIRE EFFECTS:
Fire has several indirect effects on American marten, including effects on abundance, habitat use, cover, and food. Early researchers perceived fire as having largely negative effects on American marten due to the elimination of habitat ([41,79,139], reviews by [119,179]) or potential decimation of populations ([107], reviews by [22,96,97,137]). One source states that a "forest fire of 100 square miles means the destruction of all martens within that 100 square miles. They cannot escape. The smoke pursues the fugitives and overcomes them. Their food is destroyed in the stricken area" (Seton 1929 as cited in [107]). Although fire may have substantial short-term impacts on American marten populations, it is generally accepted that fire can have long-term benefits for American marten because it creates a mosaic of successional stages offering a variety of resources ([65,94,96], reviews by [23,97,119,179]). The short- and long-term effects of fire on American marten likely depend on several factors, including fire severity (reviews by [94,96,103,161]), fire pattern [103,161], fire size (reviews by [94,96]), time since fire [8,65,94,96,103,139], characteristics of regenerating vegetation [103,161], and local site characteristics ([94,96,161,178], review by [28]).

This section summarizes indirect fire effects on the American marten, presenting a synthesis of broad indirect fire effects as well as 2 detailed wildfire case studies containing habitat descriptions, wildfire descriptions, and specific information on American marten response to wildfire.

- **Response to fire and use of burned areas**
- **Fire effects on cover**
- **Fire effects on food**
- **Wildfire Case Study 1**
- **Wildfire Case Study 2**

**Response to fire and use of burned areas:** Fire may indirectly affect American marten abundance, home range characteristics and use, dispersal, and mortality.

Fire effects and abundance: Fire may temporarily displace American marten, as was suggested following the 1988 Yellowstone fires [67]. American marten have been detected immediately following fire [139] and in areas regenerating from fire over a wide range of stand ages. In Sequoia-Kings Canyon National Park, several American marten were detected from May to mid-October at sites with a recent history of fire (prescribed fire, wildfire from natural or accidental ignition). There were >10 American marten detections in areas burned in the past 2 to 30 years [68]. Interviews from trappers in interior Alaska suggested that there was no consistent numerical response of American marten to fire; some trappers observed higher American marten abundance in burned areas, while others observed lower abundance or complete absence in burned areas [88,161]. Trappers also noted that in areas with established American marten populations, extensive use of burned areas by American marten could occur as soon as 1 to 3 years after fire. High populations often developed within 3 to 5 years in some areas, though populations in other areas did not recover for 6 to 10 years [161]. Two juvenile American marten were found only in unburned bog habitats immediately after a 160,000-acre (65,000 ha) mixed-severity fire in a black spruce forest in southeastern Manitoba. Six months after the fire, one individual spent 86.0% of its time on burnt coniferous ridges and only 6.7% of its time in unburned bogs [139].

It is difficult to determine how American marten abundance changes over time in burned areas, because no studies to date (2010) had documented long-term trends from a single area. While a few studies present data from burned areas of different ages, the results are not comparable due to different times since fire, American marten survey methods, fire characteristics, and local differences in plant community response to fire. In burned boreal forest (white spruce, black spruce, paper birch, quaking aspen, balsam poplar) of interior Alaska, American marten track densities were higher in an area burned 6 years previously compared to an area burned 35 years previously [65]. One study found American marten abundance increased with time since fire. On the Kenai Peninsula, American marten were detected 4 times as frequently in forests regenerating from a wildfire 59 years previously compared to forests regenerating from a wildfire 37 years previously. The older forest—comprised of mature black spruce—contained "ample cover and structure for supporting marten and their prey", while the younger forest—containing a mixture of northern hardwood species and immature coniferous saplings—lacked appropriate cover, structure, and potentially prey habitat [8].

Other than the observations by trappers that some areas may experience higher American marten abundance following fire [161], only 1 source suggests that American marten numbers may increase following fire. A review of the effects of fire on furbearers reports that 15 to 18 years after a "large" forest fire in Yukon, 8 American marten were harvested in a burned area where none had been harvested previously [22].

A few studies report low detection rates or use of burned areas by American marten. In Ontario, American marten were essentially absent from "recently burned-over areas" of regenerating mixed or pure stands of quaking aspen and/or paper birch. The burned areas offered little cover and few denning options in trees [46]. In northwestern Montana, researchers had limited live trapping success in burned areas; trapping success was highest along the edge between a mature mixed-conifer forest and young lodgepole pine forest [77]. In southwestern Montana, American marten exhibited low use of areas burned 1 to 2 years earlier [53]. In eastern Newfoundland, black spruce-balsam fir forests that had burned approximately 15 to 20 years earlier had <25% canopy cover; American marten used these forests less than expected based on availability, while mature black spruce-balsam fir forests were used more than expected ($P<0.05$) [66]. In southeastern Labrador, American marten used black spruce-balsam fir forest burned 42 years previously in proportion to its availability [156].

One study documented higher American marten abundance in burned areas than in unburned areas and in a younger burned area than in an older burned area. American marten relative abundance was studied in burned and unburned boreal forests in interior Alaska by sampling winter tracks. Two burned areas of different ages were located in the study area: one 282,000-acre (114,000 ha) area that burned approximately 6 years prior to the study (younger burned area) and a 2 million-acre (829,000-ha) area that burned 35 years prior to the study (older burned area). At the time of sampling, the younger burned area was in the moss-herb/tall shrub-sapling stage of succession, with grasses, fireweed (*Chamerion angustifolium*), paper birch, quaking aspen, and balsam poplar dominating. The site was littered with fallen trees, contained abundant standing dead spruce, and had many inclusions of live, mature spruce and deciduous trees. The older burned area was in the dense tree stage of forest succession, with mosaics of pure and mixed stands of white spruce, quaking aspen, paper birch, balsam poplar, and willow. Across the entire study area, including both burned and unburned forest, some of the highest American marten track densities were found near or inside the younger burned area, concentrated around the perimeter. American marten track densities were higher in the younger burned area compared to the older burned area. The authors attributed this pattern to the high levels of deadfall and presumably abundant small mammal populations in the younger burned area [65].

Average density of American marten tracks inside and outside of the perimeter of an area burned 6 years previously in interior Alaska. Adapted from [65].

| | Average tracks/km (range) | |
|---|---|---|
| | 1985 (*n*=13) | 1986 (*n*=14) |
| Inside | 1.33 (0.31-3.64)* | 2.11 (0.76-4.16)** |
| Outside | 0.90 (0.21-1.75)* | 1.16 (0.12-2.03)*** |

*Values with different numbers of * are significantly different ($P<0.1$).

One author suggests that wildfire in south-central Alaska may have prevented American marten from dispersing through several narrow valleys from the eastern to the western side of the Kenai Peninsula, resulting in low overall abundance [5].

Fire effects and home range: American marten have large home ranges, and though individuals may exhibit high fidelity to an established home range, they often use core areas of their home range, may shift their home range boundaries, or may make major movements within home ranges on a routine basis. American marten are also capable of long-distance dispersal (see Home range for more information). These characteristics of home ranges, patterns of use, and mobility likely help minimize the negative effects of fire on American marten.

One study from northwestern Montana reported that home range boundaries seemed to coincide with the edge of large open meadows and burned areas [78]. Several studies have documented American marten with home ranges largely or entirely within burned areas [88,103,109,178]. Twenty-one years after a taiga wildfire in the Northwest Territories, 11 of 12 adult American marten had home ranges that incorporated 3% to 92% of the burned area (*x*=53%). Home ranges of 1 adult and 1 juvenile were entirely within the burned area. The authors concluded that the majority of individuals used the burned area extensively but not intensively. They also observed that home range size was large in this area compared to other studies [103]. See Wildfire Case Study 1 and Wildfire Case Study 2 for additional examples of American marten predominantly using burned areas.

Though it seems likely that American marten home ranges may shift in response to postfire conditions, only one study has documented home range use before and after fire. Immediately after a 160,000-acre (65,000 ha) mixed-severity fire in boreal forest of southeastern Manitoba, one juvenile female increased her use of black spruce-tamarack bogs in the snow-free season. While home range size did not change after the fire, black spruce-tamarack bogs comprised 32.9% of her home range prior to the fire, and 35.2% after the fire. Bogs were the only cover type that did not burn in the fire [139,140].

Fire effects and dispersal: Though some studies have documented dispersal through or from burned areas [88,103,109,139,178], it is not clear that postfire conditions caused the dispersal. Immediately following a 160,000-acre (65,000 ha) mixed-severity wildfire in the boreal forests of southeastern Manitoba, a juvenile male was located for 2 weeks in unburned black spruce-tamarack bogs before radio contact was lost. This individual was eventually killed by a trapper 38 miles (61 km) away. The author suspected that dispersal was caused by postfire conditions, but the juvenile may not have established a territory prior to the fire, making dispersal inevitable [139]. See Wildfire Case Study 2 for additional examples of American marten dispersing from a burned area.

Fire effects and mortality: It is not clear whether American marten mortality rates increase following fire. In Alaska, researchers suggested that mortality may be higher for American marten with home ranges within burned areas compared to those that have at least part of their home range in unburned habitat, though the authors admitted that this assertion was based on a small sample size and circumstantial evidence [109].

Use of burned areas for specific life history activities: American marten have been documented using burned areas for foraging and hunting, resting, traveling, and reproduction.

Several studies have documented American marten using burned areas for hunting or foraging [23,88,91,109,123,161,178] (see Wildfire Case Study 1 and Wildfire Case Study 2 ). Biologists with the Alaska Department of Fish and Game observed American marten foraging along the edges of recently burned forest [91]. Approximately 20 years after fire in northwest Montana, a juvenile American marten was observed hunting on and under large-diameter logs (>15 inches (40 cm)) in open areas along a creek in regenerating lodgepole pine forest [23]. See Fire effects on food for more information.

A few studies have documented American marten resting in burned areas [109,139,178]. In the summer following a 160,000-acre (65,000 ha) mixed-severity wildfire in the boreal forests of southeastern Manitoba, one resting site was located on the edge of an unburned black spruce-tamarack bog and was formed by the roots of a fallen jack pine [139]. See Wildfire Case Study 1 for more information.

American marten may travel through burned areas ([43,53], review by [28]). In southwestern Montana, radio-collared American marten crossed through extensive areas burned 1 to 2 years previously but were never located within the areas via radio-telemetry or snow tracking [53]. One American marten in Montana moved 7 miles (11 km) in 1 day, traveling through large areas of coniferous forest burned 4 years previously [43]. In Alaska, American marten routinely traveled through and within black spruce forest burned by wildfire 7 to 8 years previously [109]. See Wildfire Case Study 1 for more information.

One study has documented American marten reproduction in a burned area. In the Northwest Territories, one female's home range contained unburned black spruce taiga and black spruce taiga regenerating 21 years after a high-severity wildfire. She denned in the burned area and produced young [103]. In central Alaska, biologists found low ovulation rates, high population turnover, high dispersal frequency, and a juvenile-biased age structure in early postfire seres, suggesting that recently burned areas lacked the conditions necessary for successful reproduction [123]. See Wildfire Case Study 2 for more information on this study.

**Fire effects on cover:** Fire may result in a short-term loss of cover (reviews by [23,96,189]) through consumption of woody structures ([46], review by [68]) and/or reduction of canopy cover [46,66,109,123,178]. However, fire may also create structures used for cover; many sources suggest that American marten use of burned areas is related to postfire structural diversity [104], including abundant snags ([65], review by [68]), downed wood ([65,109,123,161,178], review by [28]), and dense herbaceous growth ([109,178], review by [28]). Postfire activity may be concentrated around deadfall, as was documented in southwestern Yukon 25 years after a high-severity wildfire [155]. Similarly, researchers in northwestern Montana observed a juvenile hunting on and under large-diameter logs (>15 inches (40 cm)) in a regenerating lodgepole pine forest approximately 20 years after fire, despite a lack of canopy cover [23]. Downed woody structures or herbaceous vegetation appear to provide adequate cover in place of canopy cover ([23,109,123,178], review by [28]). See Wildfire Case Study 1 for more information on the extensive use of deadfall by American marten 7 to 8 years following wildfire in Alaska.

Local habitat features, such as the presence of riparian areas or a mosaic of burn patterns, may improve the suitability of burned areas for American marten by providing adequate cover. See Wildfire Case Study 1 for information about the importance of riparian areas in providing cover after wildfire. Several studies have documented American marten use of unburned inclusions within burned areas [43,53,109,155,161,178], though one study in central Alaska did not detect selection for unburned inclusions [88,123]. Such inclusions have been used as resting sites [53,139], and interviews with trappers in interior Alaska suggested that unburned inclusions and the edges of burned areas were often centers of American marten activity [161]. In southwestern Yukon, 15 American marten used an area burned by severe wildfire about 25 years previously. The burned area had sparse lodgepole pine, quaking aspen, and willow regeneration, abundant deadfall, and a few small (<25 acre (10 ha)) unburned inclusions. American marten activity was concentrated around deadfall and the unburned inclusions [155]. Ten months after wildfire in southwestern Montana, one individual was located in an unburned 1.2-acre (0.5 ha) island of lodgepole pine forest within the burned area, approximately 0.6 mile (1 km) from contiguous, unburned lodgepole pine forest [53].

Nearby intact forest may also provide important habitat for American marten using burned areas. Intact spruce (*Picea* spp.) forest adjacent to burned areas was listed as a center of American marten activity by trappers from central Alaska [161]. Also in central Alaska, winter track surveys suggested high American marten use of unburned spruce forest adjacent to an area that burned 8 years previously [84]. In southwestern Yukon, 25 years after a severe wildfire, 13 transplanted, transient American marten spent a few days in a burned area with lodgepole pine, quaking aspen, and willow, but returned to unburned white spruce forest [155]. The ecotone between burned and unburned areas has been described as excellent foraging habitat for American marten ([91], review by [189]), offering both cover and access to prey items. The proximity of intact forest may also impact the ability of American marten to colonize burned areas by providing a source population [123].

American marten often use the edges of burned areas ([88,91,161], review by [189]) but also use or travel through the interior of burned areas [53,103,109,155]. In southwestern Yukon, 25 years after a severe wildfire, 13 transplanted, transient American marten moved ≥10 miles (20 km) into the burned area at times [155].

**Fire effects on food:** American marten consume a wide variety of foods throughout their range, preferring certain food items in some areas and not others. Different prey species also have variable habitat needs, all of which might be impacted differently by fire or other ecological factors [88] (see Food Habits). A generalist diet and variability in prey habitat preferences makes it difficult to make broad generalizations about the impact of fire on American marten food resources. Numerous sources suggest that fire alters American marten food availability, largely through changes in diversity and/or abundance ([8,91,94,96,109,123,150,155,161,178], reviews by [68,189]). Some sources suggest that food resources may be reduced immediately after fire [23,96], while reviews suggests that certain food resources may be more available or abundant after fire [65,68,119,189], at least during the snow-free seasons [22,179]. Trappers in central Alaska attributed American marten presence in burned areas to an increase in microtine (Microtinae) rodents, the presence of berries, and the availability of downed timber available after fire [161]. In interior Alaska, small mammal species diversity was greater in black spruce forest burned by wildfire 7 to 8 years previously compared to unburned areas, and small mammal abundance in burned areas was equal to or surpassed that in unburned areas. Meadow voles (*Microtus* spp.), considered the preferred prey in this study area, were more common within the burned area, while red-backed voles (*Myodes* spp.) were more common outside the burned area [109]. See Wildfire Case Study 1 for more information on this study. Similar results were documented in a different study area in interior Alaska; American marten abundance was highest in an early postfire sere (postfire years 6-9) containing a mixture of birch (*Betula* spp.) and black spruce regeneration. This postfire sere had the highest abundance of yellow-cheeked voles, a preferred food item. This postfire sere also contained more diverse prey items and lacked the fluctuations in northern red-backed vole (*M. rutilus*) populations observed in other postfire seres [88]. See Wildfire Case Study 2 for more information on this study.

In east-central Alaska, the abundance and diversity of potential American marten small mammal prey differed between approximately 24-year-old quaking aspen stands regenerating from a severe fire and unburned black and white spruce forest. Northern red-backed voles were ubiquitous across cover types, while yellow-cheeked voles were most abundant in the burned habitat. Both species were potential prey items, though their relative value to American marten in this study area was not discussed. Over the 3 years of study, microtine rodent populations declined in burned forests and showed no clear trend in unburned forest. The author did not attribute small mammal population declines in burned areas to postfire conditions or any other factor. The study area did experience unusually cold spring temperatures [150].

Relative abundance of small mammals captured during August 1991-1993 in areas severely burned approximately 24 years previously and unburned areas, Yukon-Charley Rivers National Preserve, Alaska [150]

| Small mammal species | 1991 | | 1992 | | 1993 | |
|---|---|---|---|---|---|---|
| | Burned | Unburned | Burned | Unburned | Burned | Unburned |

| | | | | | | |
|---|---|---|---|---|---|---|
| All microtine rodents | 24.7 | 7.3 | 11.9 | 11.5 | 5.6 | 2.5 |
| Northern red-backed vole | 13.9 | 6.3 | 7.8 | 10.8 | 4.9 | 2.2 |
| Yellow-cheeked vole | 10.8 | 0.9 | 4.1 | 0.5 | 0.7 | 0.2 |
| Shrews (Soricidae) | 6.8 | 4.2 | 1.5 | 0.6 | 7.1 | 3.9 |

The ability of burned areas to provide preferred food items may be related to several factors, including those related to fire (e.g., severity, size, time since fire) or local site characteristics (e.g., moisture regime). On the Kenai Peninsula, black spruce forest burned 59 years previously had sufficient cover to support American marten prey. However, a young forest of northern hardwoods and immature conifer saplings that burned 37 years previously did not [8]. Approximately 12 years after wildfire on mesic sites in north-central Idaho, one plot that experienced low-severity surface fire supported American marten prey, while another plot that experienced high-severity fire did not. Microtine rodents, occurring in 71% of summer-fall scats, were abundant in areas burned 40 to 60 years previously or in mesic sites within meadows. Areas burned 10 to 15 years previously and exhibiting xeric conditions supported high numbers of deer mice, which were not a favored prey item, and supported few microtine rodents [94,96].

While most studies examining American marten food items and fire concentrate on small mammals, it is also likely that fire affects the abundance and availability of plant species used as forage, particularly berries. American marten summer diets in north-central Idaho contained high amounts of fruits, insects, and ground squirrels, all of which were available in open meadows and burned areas [94,96]. Seven to 8 years after wildfire in Alaska, Vernam [178] noted that berry production was highest in extensive areas of burned open meadows and black spruce forest, which may have caused American marten to expand their home range into burned areas in the summer. See Wildfire Case Study 1 for more information on this study.

For more information on fire effects on American marten food items, see the following FEIS reviews: snowshoe hare, red squirrel, northern red-backed vole, meadow vole, deer mouse, Alaska blueberry, and ovalleaf huckleberry.

**Wildfire Case Study 1** Two related studies examined American marten use of habitat in and surrounding an area in interior Alaska burned by wildfire 7 to 8 years previously.

Habitat and wildfire description: The Bear Creek Fire burned approximately 350,000 acres (140,000 ha) of black spruce forest interspersed with wet meadows, bogs, and white spruce stands along waterways. The fire was of mixed severity and intensity. In many areas, riparian white spruce stands survived the fire. In other areas, overstories ranged from unburned to partially burned and completely burned. Completely burned areas had some live trees but they were confined to riparian stringers or small inclusions, while partially burned areas had at least 50% live trees evenly scattered throughout the area [109]. Five cover types were defined: white spruce (white spruce, paper birch, and balsam poplar); open conifer (tamarack and black spruce)-wet meadow (grass-sedge); black spruce; and wet meadow. At the time of sampling (postfire year 8), none of the burned cover types contained live overstory trees, and shrub layers were not well developed; in black spruce and white spruce cover types, shrub cover was 22% to 23% [178]. The fire was of mixed severity and intensity. In many areas, riparian white spruce stands survived the fire. In other areas, overstories ranged from unburned to partially burned and completely burned.

Conversations with local trappers suggested that American marten were present in the study area prior to the fire and populations were at a similar density after the fire [178]. Winter surveys 3 years after the fire found American marten tracks in the burned area, though quantity and habitat associations were not reported [84]. To investigate home range and habitat use 7 to 8 years after the fire, 16 American marten were radio-collared in and adjacent to burned area and their movements were observed over 2 years [109]. Sample size for analyses of home range and habitat use varied.

Home range composition: All American marten home ranges included both burned and unburned habitat. Many of the American marten home ranges were in areas with essentially no forest canopy [178]. Of 134 American marten locations, 44% were in burned areas and 14% were in a mixture of burned and unburned areas. One individual's home range was entirely within the burned area; the home ranges of other individuals ranged from 0 to 69% burned habitat [109].

Selection of cover types or habitat features within home ranges: Within home ranges, American marten generally used cover types in proportion to their occurrence, though selection for cover types varied by individual. One male used some habitats selectively, preferring unburned forests and avoiding unburned wet meadows ($P<0.05$). Compared to the larger landscape, American marten home ranges in the vicinity of the Bear Creek Burn appeared to have greater habitat heterogeneity [178]. For the individual male living entirely within the burned area, where live tree cover was nearly absent (*x*=10 live trees/ha), wind-thrown trees, herbaceous vegetation, and snow tunnels were used for cover. This individual was most often found in wind-thrown timber in riparian areas; he avoided large, open windy areas (e.g., lakes and meadows) with hard snowpack, little vegetation, or little log debris above the snow [109].

Burned riparian areas were important features of the postfire landscape. Within the burned area, American marten were most abundant in burned riparian stands of white spruce, where large-diameter trees toppled quickly after fire [109]. The association with riparian areas was attributed to high levels of dead and downed wood that offered suitable overhead cover and foraging habitat. Vertical layering of log debris provided numerous snow-free tunnels and passageways that American marten used frequently. American marten were observed resting under wind-thrown trees, and track observations indicated they probably hunted there [178]. Burned riparian areas also exhibited tall, but not dense, herbaceous vegetation and large and numerous subnivean spaces compared to areas away from burned riparian zones. American marten were less abundant in small-diameter black spruce forests where burned trees remained standing, though both plant communities were used for hunting, traveling, and burrowing in the snow [109]. Little use was made of extensive burned areas away from riparian zones, suggesting these areas lacked prey and protective cover [178].

Red squirrel middens were also important features of American marten habitat. Besides containing extensive areas of wind-thrown trees, each American marten home range in a burned cover type contained at least one active red squirrel midden within an unburned inclusion. Two females foraged in unburned white spruce, using unburned inclusions with red squirrel middens as resting sites between foraging bouts. Over a 2-month time period, one female repeatedly rested in a red squirrel midden in a small unburned stand of white spruce, several hundred meters from the closest other stands of live trees [109].

Foraging opportunities: American marten habitat associations after the Bear Creek Fire may be related to hunting and foraging opportunities. Small mammal trapping success was greatest in burned and unburned white spruce forest in riparian areas. Species diversity was greater in burned habitat, and small mammal abundance in burned areas equaled or surpassed abundance in unburned areas. Meadow voles (*Microtus* spp.), considered the preferred prey in this study area, were more common within the burned area, while northern red-backed voles were more common outside of burned cover types [109]. Berry production was highest in extensive areas of burned open meadows and black spruce forest; the author suggested that individual

American marten may expand their home ranges into these areas in summer to take advantage of berries as food [178]. Based on tracking observations, small patches of burned open conifer-wet meadow cover types were used for foraging, and burned forests were used for hunting; these cover types offered extensive wind-thrown tree cover. Outside of riparian areas, most American marten locations were in unburned white spruce inclusions that had high numbers of northern red-backed voles [178].

Resting: Both summer and winter resting sites for American marten were related to log debris; in the summer, resting sites were usually in dense tangles of wind-thrown trees, while in the winter, American marten used subnivean spaces created by piles of wind-thrown trees [109]. Of 27 confirmed resting sites of females, 11 were under the snow with access from the base of a live or dead standing tree, and 11 were in active red squirrel middens, with midden sites used repeatedly. While resting, males tended to select burned open conifer-wet meadow and white spruce forest for resting; use of burned areas as resting sites occurred in the summer. Females were observed resting most frequently in unburned white spruce and black spruce stands, as well as in burned white spruce stands [178].

Dispersal: While other studies have observed dispersal along the edges of burned areas, this study documented one individual dispersing through the interior of the burned area. The female moved 4 miles (7 km) over 2 weeks, then moved another 9 miles (15 km) in the following 2 weeks. She was killed by a predator soon after [109].

Mortality: It was hypothesized that burned areas may make American marten more vulnerable to ground predation if standing trees are important for escape and cover [178]. Based on a small sample size and circumstantial evidence, is was suggested that mortality may be higher for individuals with home ranges within burned areas compared to those that have at least part of their home range in unburned habitat, though no data were presented [109].

Conclusions: American marten were attracted to early-successional habitats and open areas such as bogs, meadows, grassy sloughs, and burned areas, all of which represented important components of habitat in interior Alaska [109]. When evaluating a burned area as American marten habitat, the amount of unburned inclusions, deadfall, small mammal populations, potential predators, conifer regeneration, and snowfall should be considered interdependently. Fire size and intensity may influence several of these features [109]. The authors suggest management for a mosaic of successional stages, which would involve retaining wildfire as a critical disturbance process [109]. Fires "are useful in maintaining habitat heterogeneity over time, a characteristic of great value in maintaining long-term marten populations" [178].

### Wildfire Case Study 2

American marten home range and habitat use of 3 postfire seres were studied over 3 winters on the black spruce taiga of central Alaska [88,123]. Availability and consumption of food items were also compared between postfire seres [88].

Habitat and wildfire description: Multiple wildfires occurred in the study area, resulting in a mosaic of cover types. In this summary, postfire seres will be referred to as early (postfire years 6-9), intermediate (postfire years 25-29), and mature (> postfire year 100). Wildfires were of variable severity, resulting in a mosaic of successional stages within the 2 youngest postfire seres. Most of the early postfire sere was in the tall shrub-sapling stage of early succession, containing a mixture of birch and black spruce regeneration. Some severely burned sites where heat penetrated the soil were still in the moss-herb stage of succession. About 6% of the early postfire sere consisted of patches of unburned, mature black spruce and tamarack forest. Most of the intermediate postfire sere was black spruce forest in the dense tree stage of succession. Severely burned lowlands were still in the shrub-sapling stage, containing a mixture of birch and black spruce. Dead, fire-scarred trees were standing in the 2 youngest postfire seres. Leaning and fallen trees created slash piles ≤5.0 feet (1.5 m) deep on ridges in the early postfire sere, whereas most slash piles had collapsed but not yet decayed on ridges in the intermediate postfire sere. The mature postfire sere was predominantly black spruce and tamarack ranging from 2 to 8 inches (5-20 cm) DBH [88,123].

In addition to postfire sere the authors also analyzed habitat selection and use based on burn feature (unburned forest, burned edge, burned interior, unburned inclusion) and forest cover type (coniferous forest, deciduous forest, mixed coniferous-deciduous forest, and scrub). Detailed descriptions of species composition of forest cover types were not presented, though it is likely coniferous forests contained black spruce and tamarack. Scrub cover types contained a mixture of birch, black spruce, and shrubs.

Home range and habitat selection: Forty-two American marten were captured and equipped with radio collars, though the number of individuals used for analyses varied based on the duration of detections [88,123]. Home ranges were determined for 8 resident individuals >1 year old. Of these individuals, 3 had home ranges entirely within the early postfire sere, 4 individuals had home ranges that were at least 50% within the early postfire sere, and 1 individual had a home range that was <25% within the early postfire sere. The intermediate postfire sere was rarely within a home range boundary [88].

Within home ranges, individual American marten habitat selection was not related to forest cover type or burn feature. Analysis of individual selection for postfire seres was not possible because only 3 of 8 individuals had all 3 seral stages in their home range. Live trapping success and winter track surveys were used as estimates of relative abundance to analyze population-level habitat use. Relative abundance of American marten differed significantly among postfire seres ($P<0.05$) [88,123].

Relative abundance of American marten over 2 years in postfire seres in black spruce taiga of central Alaska [88,123]

| Postfire year | Relative abundance (captures/100 trap nights) | | | | |
|---|---|---|---|---|---|
| | Spring 1991 | Fall 1991 | Spring 1992 | Fall 1992 | All periods* |
| 6 to 9 | 2.3 | 5.5 | 2.1 | 2.2 | 2.9 |
| 25 to 29 | 0 | 0 | 0.6 | 0 | 0.3 |
| >100 | 1.2 | 1.4 | 2.5 | 0 | 1.6 |

*Pair-wise comparisons between all 3 postfire seres were significantly different ($P<0.05$).

Abundance estimated by trapping success was greatest in the early postfire sere, followed by the mature postfire sere. Only 2 of 42 individuals were captured in the intermediate postfire sere. A similar pattern was seen when using track surveys to estimate relative abundance. American marten tracks were most abundant in the early postfire sere and least abundant in the intermediate postfire sere; all pair-wise comparisons between postfire seres were significantly different ($P<0.05$). The early postfire sere had the lowest canopy cover but the highest coarse woody debris density ($P=0.009$). This postfire sere also had the highest prey biomass, prey diversity, and subnivean and supranivean hunting investigation rates. Hunting investigation rates were 2nd highest in the mature postfire sere, followed by the intermediate postfire sere. The intermediate postfire sere had the least stable prey base, with low prey diversity and an absence of some preferred prey species [88,123].

Habitat use differed between transient and resident individuals. Although both transients and residents were relocated less often in the mature postfire sere than the early postfire sere, the disparity was greater for transients (17% in the mature postfire sere vs. 83% in the early postfire sere) than residents (33% vs. 66%). Transients were located more often in the scrub cover type and less often in coniferous forests than residents. More residents than transients were found in unburned forest, and more transients than residents were found in burned forest. This disparity was greater for transients (16.6% in unburned forest vs. 69.5% in burned forest) than residents (32.9% in unburned forest vs. 12.0% in burned forest) [88,123].

*Population structure and dispersal:* Several population characteristics led the authors to suggest that the early postfire sere may be an American marten population sink. High turnover of individuals, high frequency of presumed dispersal, juvenile-biased age structure and low ovulation rates in adult females in the study area suggest that the conditions necessary for reproduction may be lacking in early postfire seres [88,123]. Commercial trapping harvested more juveniles than adults in the early postfire sere compared to the mature postfire sere ($P<0.01$). Few adult females were harvested in the early postfire sere. Ovulation rates were low throughout the study area; only 8% of 25 females were classified as reproductive within the study area compared to 62% of 21 females sampled outside of the study area [88,123]. Dispersal from the earliest postfire sere appeared high, though it was not clear whether the 3 dispersing individuals were born in the early postfire sere or merely captured there [88].

*Food availability and consumption patterns:* To investigate whether or not American marten abundance in postfire seres was related to food availability, small mammal and berry abundance were measured in autumn over 4 years. In general, the highest density of berry-producing plants occurred in the early postfire sere, though density was extremely variable in all cover types due to small-scale variation in site moisture conditions. The northern red-backed vole was the most abundant and widespread small mammal species, though populations fluctuated "wildly" between years in both the intermediate and mature postfire seres. Shrew numbers were highly variable among all years in all seres. Yellow-cheeked voles were most abundant in the early postfire sere and absent from the intermediate postfire sere. Small mammal diversity was highest in the early postfire sere [88].

Approximate average relative abundance of potential American marten small mammal prey in autumn in 3 postfire seres in interior Alaska. Adapted from [88].

| Postfire year | Year | Average relative abundance (captures/100 trapnights) | | |
|---|---|---|---|---|
| | | Northern red-backed vole | Voles* | Shrews |
| 6 to 9 | 1991 | 1.0 | 0.6 | 2.5 |
| | 1992 | 5.0 | 1.0 | 1.0 |
| | 1993 | 4.0 | 0.6 | 3.0 |
| | 1994 | 4.5 | 0.4 | 1.5 |
| 25 to 29 | 1991 | 0.5 | 0.03 | 3.0 |

| | | | | |
|---|---|---|---|---|
| | 1992 | 8.0 | 0.04 | 2.0 |
| | 1993 | 3.5 | 0.03 | 4.5 |
| | 1994 | 1.0 | 0.02 | 3.5 |
| >100 | 1991 | 1.5 | 0.03 | 1.8 |
| | 1992 | 6.5 | 0.5 | 1.5 |
| | 1993 | 3.5 | 0.17 | 3.6 |
| | 1994 | 1.0 | 0.02 | 2.5 |
| *Primarily yellow-cheeked voles; meadow voles (*Microtus pennsylvanicus*) were present but rare in study area | | | | |

Winter scats were collected from all postfire seres, though sample size was low in the intermediate postfire sere (*n*=9 scats) compared to the early postfire sere (*n*=40) and the mature postfire sere (*n*=26). Pooled results indicated that microtine voles were the most frequent food item (occurred in 58.3% scats), followed by northern red-backed voles (25.0%), shrews (7.9%), and berries (6.3%). The relative frequency of microtine voles, northern red-backed voles, and shrews did not differ between postfire seres, indicating that microtine voles were the preferred food item in all seres.

The authors reported that the relationship between food availability and American marten abundance in postfire seres was not clear. However, their data suggest that American marten abundance may be related to preferred food availability. American marten abundance was consistently highest in the early postfire sere, which had the highest abundance of yellow-cheeked voles. This postfire sere contained more diverse prey items and lacked the fluctuations in northern red-backed vole populations observed in other postfire seres, prompting the authors to label it the postfire sere with the "most stable prey base". American marten abundance was low in the intermediate postfire sere, where berry abundance was also low but northern red-backed voles (a less favored food item than yellow-cheeked voles) showed an 8-fold population increase over the course of the study [88].

Conclusions: The results of this study suggest that American marten are not confined to late-successional seres, and that they use standing deadfall and wind-thrown trees as winter cover before coniferous regeneration develops in recently burned forest. Use of early postfire seres may be related to high prey abundance and diversity. The lack of selection for burn features, particularly unburned inclusions, contradicts existing hypotheses suggesting that coniferous overstory is required by American marten within or near burned forests. However, this study also found the early postfire sere was predominantly used by nonbreeding individuals, suggesting that recently burned areas may act as a population sink for immature and transient individuals dispersing from nearby mature coniferous forest [88,123]. The authors caution against using fire to manipulate the mosaic of postfire seres in the taiga of Alaska until the habitat needs of breeding individuals are better understood [88].

FIRE REGIMES:
Fire is a natural disturbance shaping plant communities across the range of the American marten, including plant communities in Alaska [24,65,150,178], Wisconsin [63,186], Montana [23,181], Idaho [93,96], Washington [94], California [111,159], Northwest Territories [131], , Yukon [3,155], Ontario [1], Manitoba [140,141], and British Columbia [6,106]. American marten occur in plant communities with a wide range of fire regimes, including fire regimes characterized by low-severity (e.g., California redwood; Great Lakes maple-basswood), mixed-severity (e.g., California mixed evergreen; Douglas-fir (cold)), or stand-replacement (e.g., Pacific Northwest spruce-fir; persistent lodgepole pine) fire. Return intervals may be either short (e.g., Sierra Nevada lodgepole pine; ponderosa pine (Northern and Central Rockies)) or long (e.g., western redcedar; northern hardwoods-spruce; beech-maple).

The Fire Regime Table summarizes characteristics of fire regimes for vegetation communities in which American marten may occur. Follow the links in the table to documents that provide more detailed information on these fire regimes. Find further fire regime information for the plant communities in which this species may occur by entering the species name in the FEIS home page under "Find Fire Regimes".

American marten also occur in geographic areas not covered by the Fire Regime Table, including a variety of boreal plant communities in Alaska and Canada. On the Kenai Peninsula, mean fire-return intervals ranged from 400 to 600 years for white spruce forest and averaged 79 years for black spruce forest (review by [8]). The boreal white spruce-black spruce biogeoclimatic zone in northeastern British Columbia experienced historic stand-replacing fires approximately every 100 years. Most fires were large (>2,500 acres (1,000 ha)), leaving small amounts of unburned forest (review by [132]). A mean fire-return interval of 69 years was estimated for boreal white spruce forests in Wood Buffalo National Park, Alberta [102]. In the interior taiga of Alaska, black spruce-paper birch/bog blueberry-bog Labrador tea (*V. uliginosum-Ledum groenlandicum*) and black spruce/bog blueberry-bog Labrador tea/Schreber's moss (*Pleurozium schreberi*) vegetation types had fire return intervals of less than 100 years [56]. From fire scar data, a mean fire-return interval of 40.4 years was calculated for the jack pine-black spruce/bog Labrador tea/reindeer lichen (*Cladonia* spp.) vegetation type occupying north-facing slopes and depressions of the Athabasca Plains of northeastern Alberta and northwestern Saskatchewan [33].

Fire regime change: Climate change may have important implications for fire regimes in areas where American marten occur. One author suggested that fire frequency on the Kenai Peninsula may be increasing in response to warmer summer temperatures, causing a potential decline in suitable American marten habitat [8]. There is some concern that fire exclusion has increased fuel loads, altering historical fire regimes and resulting in severe fires that could negatively impact American marten habitat (review by [96]). However, since fire regime characteristics across the distribution of American marten are variable, it is difficult to say how representative this assertion is for all American marten habitats.

## FIRE MANAGEMENT CONSIDERATIONS:

American marten populations exhibit several characteristics that may inhibit recovery from large-scale disturbances such as fire; these characteristics include generally low population density, low reproductive rates, delayed maturity, and the geographic isolation of some populations (see Management Considerations).

Some sources suggest that prescribed fire may be an appropriate tool for managing forests for American marten [2,114,124], though, as of this writing (2010), no studies had directly studied this topic. The authors of one study caution against using fire as a management tool in the taiga of Alaska, after documenting several population characteristics that suggested recently burned forest may act as a population sink [88] (see Wildfire Case Study 2). The effects of wildfire on American marten depend on several factors, including fire severity ([94,94], reviews by [103,161]), fire pattern [103,161], fire size [22,94,96], time since fire [8,65,94,96,103,139], characteristics of regenerating vegetation [103,161], and local site characteristics ([94,96,161,178], review by [28]) (see Indirect Fire Effects for more information). It is likely the effects of prescribed fire depend on similar factors.

This section summarizes some of the topics to consider before using prescribed fire in areas occupied by American marten, including potential impacts on American marten and a synthesis of fire characteristics that would minimize negative impacts. There is also a brief mention of fire surrogate treatments.

**Potential Impacts:** As is the case with fire in general [108,114,130], the likelihood of American marten mortality due to prescribed fire is low, with the possible exception of kits if prescribed fires are conducted in the spring denning season (review by [68]). One review reports that mammalian predators such as the American marten have such large home ranges that prescribed fire treatments would likely represent a minimal proportion of their home range [114].

Prescribed fire has the potential to consume denning and resting structures as well as reduce canopy cover, though one source suggests that prescribed fire's impact on protective cover is likely to be negligible [114]. Management recommendations for American marten in British Columbia include avoiding practices such as windrowing and burning, stump removal, or severe broadcast burning because such practices consume woody debris [105]. Suggestions for protecting woody structures include wetting them or burning in moist conditions [70,114] raking debris away from their bases [48,114,175] or applying fire retardant at bases of snags [114]. Downed woody structures or herbaceous vegetation may provide adequate cover in place of canopy cover following prescribed fire; such resource use by American marten has been reported following wildfire ([23,109,123,178], review by [28]), insect outbreaks [126], or logging [81]. For information on wildlife habitat and preservation during and after fires, including information on managing for structures used by American marten, see Brown and Bright [15].

As is the case with wildfire (see Fire effects on food), it is difficult to make broad generalizations about the potential impacts of prescribed fire on American marten food resources due to regional diet preferences and prey habitat variability (see Food Habits). It is likely that prescribed fire will increase the abundance of some food items and decrease the abundance of others. One review suggests that prescribed fire would likely increase the short-term quantity of food available [114]. Within 4 years of a mixed-severity prescribed fire in central Alaska, researchers observed "diggings" of yellow-cheeked voles, a preferred American marten prey item in the area [124]. However, Pilliod and others [130] summarize cases where small mammal populations declined following thinning treatments that included prescribed fire.

**Fire characteristics:** There are several aspects of prescribed fire to consider when attempting to produce conditions favorable to American marten, including fire season, size, severity, and burn pattern. Fire season is important because American marten kits may be vulnerable to mortality from prescribed fires conducted during the denning season, which begins in late March or April (review by [136]). Several sources recommend small prescribed fires ([91,161], reviews by [22,96]) because small disturbed areas usually require less time to reestablish cover and food than large areas (review by [96]) or may create abundant edge habitat, favored for foraging in some areas [91]. Small fires may also decrease the risk of habitat fragmentation, which is generally thought to negatively affect American marten ([75,80,81,116,180], review by [27]). Johnson and others [88] suggest that large fires with few unburned inclusions would be colonized more slowly than small or patchy fires that may be closer to source populations in unburned forest. Low-severity fires may also be ideal if they maintain canopy cover (review by [96]), though one source suggests fires of variable severity may offer a diversity of resources [161]. Burn pattern is also an important consideration. Unburned inclusions are highly used cover types in areas burned by wildfire [43,53,109,155,161,178] (see Fire effects on cover). Proximity of residual forest may also be important [58,91], particularly if it impacts the ability of American marten to colonize burned areas [2,123]. One source suggests that fires with irregular perimeters are highly beneficial to American marten in Alaska because burn edges are often a center of activity [161]. To minimize the negative impacts of prescribed fires on American marten in south-central Yukon, treatments that leave pockets of mature forest, protect old-growth communities, and allow enough intact forest to allow for immigration and emigration are suggested [2].

**Other fire-related treatments:** Though the information is sparse and/or indirect, as of this writing (2010), there was some commentary on the impacts of fire-surrogate treatments on American marten. Mechanical fuels reduction treatments in northeastern Oregon led to changes in small mammal populations, including general decreases in populations of northern red-backed voles, red squirrels, and snowshoe hares. Though American marten food habits were not studied, the authors noted that American marten avoided all treated areas [17].

Though details are lacking, managers from central Alaska observed more winter tracks of American marten in quaking aspen stands regenerating after felling compared to stands burned by severe prescribed fire. Both treatments occurred 2 to 6 years previously and top-killed most quaking aspen. Debris was removed from sites where felling occurred. At the time of sampling, both treatment areas had 30,000 stems/ha [122].

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# APPENDIX: FIRE REGIME TABLE

SPECIES: Martes americana

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The following table provides fire regime information that may be relevant to American marten habitats based on descriptions in available literature. Find further fire regime information for the plant communities in which this species may occur by entering the species name in the FEIS home page under "Find Fire Regimes".

Fire regime information on vegetation communities in which American marten may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [101], which were developed by local experts using available literature, local data, and/or expert opinion. This table summarizes fire regime characteristics for each plant community listed. The PDF file linked from each plant community name describes the model and synthesizes the knowledge available on vegetation composition, structure, and dynamics in that community. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

| Pacific | California | Southwest | Great | Northern and Central |
|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Northwest Basin Rockies<br>Great Lakes Northeast | | | | | |
| **Pacific Northwest** | | | | | |
| Vegetation Community (Potential Natural VegetationGroup) | Fire severity* | Fire regime characteristics | | | |
| | | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |
| Northwest Forested | | | | | |
| Ponderosa pine (xeric) | Replacement | 37% | 130 | | |
| | Mixed | 48% | 100 | | |
| | Surface or low | 16% | 300 | | |
| Lodgepole pine (pumice soils) | Replacement | 78% | 125 | 65 | 200 |
| | Mixed | 22% | 450 | 45 | 85 |
| Pacific silver fir (low elevation) | Replacement | 46% | 350 | 100 | 800 |
| | Mixed | 54% | 300 | 100 | 400 |
| Pacific silver fir (high elevation) | Replacement | 69% | 500 | | |
| | Mixed | 31% | >1,000 | | |
| Mixed conifer (eastside dry) | Replacement | 14% | 115 | 70 | 200 |
| | Mixed | 21% | 75 | 70 | 175 |
| | Surface or low | 64% | 25 | 20 | 25 |
| Mixed conifer (eastside mesic) | Replacement | 35% | 200 | | |
| | Mixed | 47% | 150 | | |
| | Surface or low | 18% | 400 | | |
| Spruce-fir | Replacement | 84% | 135 | 80 | 270 |
| | Mixed | 16% | 700 | 285 | >1,000 |
| **California** | | | | | |
| Vegetation Community (Potential Natural VegetationGroup) | Fire severity* | Fire regime characteristics | | | |
| | | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |

| | | | | | |
|---|---|---|---|---|---|
| California Forested | | | | | |
| California mixed evergreen | Replacement | 10% | 140 | 65 | 700 |
| | Mixed | 58% | 25 | 10 | 33 |
| | Surface or low | 32% | 45 | 7 | |
| Coast redwood | Replacement | 2% | ≥1,000 | | |
| | Surface or low | 98% | 20 | | |
| Jeffrey pine | Replacement | 9% | 250 | | |
| | Mixed | 17% | 130 | | |
| | Surface or low | 74% | 30 | | |
| Red fir-white fir | Replacement | 13% | 200 | 125 | 500 |
| | Mixed | 36% | 70 | | |
| | Surface or low | 51% | 50 | 15 | 50 |
| Sierra Nevada lodgepole pine (cold wet upper montane) | Replacement | 23% | 150 | 37 | 764 |
| | Mixed | 70% | 50 | | |
| | Surface or low | 7% | 500 | | |
| Sierra Nevada lodgepole pine (dry subalpine) | Replacement | 11% | 250 | 31 | 500 |
| | Mixed | 45% | 60 | 31 | 350 |
| | Surface or low | 45% | 60 | 9 | 350 |
| **Southwest** | | | | | |
| Vegetation Community (Potential Natural VegetationGroup) | Fire severity* | Fire regime characteristics | | | |
| | | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |
| Southwest Forested | | | | | |
| Aspen with spruce-fir | Replacement | 38% | 75 | 40 | 90 |
| | Mixed | 38% | 75 | 40 | |
| | Surface or | 23% | 125 | 30 | 250 |

| | | | | | |
|---|---|---|---|---|---|
| | low | | | | |
| Spruce-fir | Replacement | 96% | 210 | 150 | |
| | Mixed | 4% | >1,000 | 35 | >1,000 |
| **Great Basin** | | | | | |
| Vegetation Community (Potential Natural VegetationGroup) | Fire severity* | Fire regime characteristics | | | |
| | | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |
| Great Basin Forested | | | | | |
| Spruce-fir-pine (subalpine) | Replacement | 98% | 217 | 75 | 300 |
| | Mixed | 2% | >1,000 | | |
| **Northern and Central Rockies**<br>• Northern and Central Rockies Grassland<br>• Northern and Central Rockies Forested | | | | | |
| Vegetation Community (Potential Natural VegetationGroup) | Fire severity* | Fire regime characteristics | | | |
| | | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |
| Northern and Central Rockies Grassland | | | | | |
| Mountain grassland | Replacement | 60% | 20 | 10 | |
| | Mixed | 40% | 30 | | |
| Northern and Central Rockies Forested | | | | | |
| Ponderosa pine (Northern Great Plains) | Replacement | 5% | 300 | | |
| | Mixed | 20% | 75 | | |
| | Surface or low | 75% | 20 | 10 | 40 |
| Ponderosa pine (Northern and Central Rockies) | Replacement | 4% | 300 | 100 | ≥1,000 |
| | Mixed | 19% | 60 | 50 | 200 |
| | Surface or low | 77% | 15 | 3 | 30 |
| Ponderosa pine (Black Hills, low elevation) | Replacement | 7% | 300 | 200 | 400 |
| | Mixed | 21% | 100 | 50 | 400 |

| | | | | | |
|---|---|---|---|---|---|
| | Surface or low | 71% | 30 | 5 | 50 |
| Ponderosa pine (Black Hills, high elevation) | Replacement | 12% | 300 | | |
| | Mixed | 18% | 200 | | |
| | Surface or low | 71% | 50 | | |
| Ponderosa pine-Douglas-fir | Replacement | 10% | 250 | | ≥1,000 |
| | Mixed | 51% | 50 | 50 | 130 |
| | Surface or low | 39% | 65 | 15 | |
| Western redcedar | Replacement | 87% | 385 | 75 | ≥1,000 |
| | Mixed | 13% | >1,000 | 25 | |
| Douglas-fir (xeric interior) | Replacement | 12% | 165 | 100 | 300 |
| | Mixed | 19% | 100 | 30 | 100 |
| | Surface or low | 69% | 28 | 15 | 40 |
| Douglas-fir (warm mesic interior) | Replacement | 28% | 170 | 80 | 400 |
| | Mixed | 72% | 65 | 50 | 250 |
| Douglas-fir (cold) | Replacement | 31% | 145 | 75 | 250 |
| | Mixed | 69% | 65 | 35 | 150 |
| Grand fir-Douglas-fir-western larch mix | Replacement | 29% | 150 | 100 | 200 |
| | Mixed | 71% | 60 | 3 | 75 |
| Western larch-lodgepole pine-Douglas-fir | Replacement | 33% | 200 | 50 | 250 |
| | Mixed | 67% | 100 | 20 | 140 |
| Grand fir-lodgepole pine-larch-Douglas-fir | Replacement | 31% | 220 | 50 | 250 |
| | Mixed | 69% | 100 | 35 | 150 |
| Persistent lodgepole pine | Replacement | 89% | 450 | 300 | 600 |
| | Mixed | 11% | >1,000 | | |
| Whitebark pine-lodgepole pine (upper subalpine, Northern and Central Rockies) | Replacement | 38% | 360 | | |
| | Mixed | 62% | 225 | | |
| Lower subalpine | Replacement | 73% | 170 | 50 | 200 |

| | | | | | |
|---|---|---|---|---|---|
| lodgepole pine | Mixed | 27% | 450 | 40 | 500 |
| Lower subalpine (Wyoming and Central Rockies) | Replacement | 100% | 175 | 30 | 300 |
| Upper subalpine spruce-fir (Central Rockies) | Replacement | 100% | 300 | 100 | 600 |
| **Great Lakes** | | | | | |
| Vegetation Community (Potential Natural VegetationGroup) | Fire severity* | Fire regime characteristics | | | |
| | | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |
| Great Lakes Forested | | | | | |
| Northern hardwood maple-beech-eastern hemlock | Replacement | 60% | >1,000 | | |
| | Mixed | 40% | >1,000 | | |
| Conifer lowland (embedded in fire-prone system) | Replacement | 45% | 120 | 90 | 220 |
| | Mixed | 55% | 100 | | |
| Conifer lowland (embedded in fire-resistant ecosystem) | Replacement | 36% | 540 | 220 | ≥1,000 |
| | Mixed | 64% | 300 | | |
| Great Lakes spruce-fir | Replacement | 100% | 85 | 50 | 200 |
| Maple-basswood | Replacement | 33% | ≥1,000 | | |
| | Surface or low | 67% | 500 | | |
| Maple-basswood mesic hardwood forest (Great Lakes) | Replacement | 100% | >1,000 | ≥1,000 | >1,000 |
| Maple-basswood-oak-aspen | Replacement | 4% | 769 | | |
| | Mixed | 7% | 476 | | |
| | Surface or low | 89% | 35 | | |
| Northern hardwood-eastern hemlock forest (Great Lakes) | Replacement | 99% | >1,000 | | |

| | | | | | |
|---|---|---|---|---|---|
| Pine-oak | Replacement | 19% | 357 | | |
| | Surface or low | 81% | 85 | | |
| Eastern white pine-eastern hemlock | Replacement | 54% | 370 | | |
| | Mixed | 12% | >1,000 | | |
| | Surface or low | 34% | 588 | | |
| **Northeast** | | | | | |
| Vegetation Community (Potential Natural Vegetation Group) | Fire severity* | Fire regime characteristics | | | |
| | | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |
| Northeast Forested | | | | | |
| Northern hardwoods (Northeast) | Replacement | 39% | ≥1,000 | | |
| | Mixed | 61% | 650 | | |
| Northern hardwoods-spruce | Replacement | 100% | ≥1,000 | 400 | >1,000 |
| Beech-maple | Replacement | 100% | >1,000 | | |
| Northeast spruce-fir forest | Replacement | 100% | 265 | 150 | 300 |

*Fire Severities—
**Replacement:** Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.
**Mixed:** Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.
**Surface or low:** Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [70,100].

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