Chapter 5

Terrestrial Fauna of Redwood Forests

Allen Cooperrider, Reed F. Noss, Hartwell H. Welsh Jr., Carlos Carroll, William Zielinski, David Olson, S. Kim Nelson, and Bruce G. Marcot

The redwood forests support an unknown but large number of invertebrate species and, over all seasons, more than two hundred species of vertebrates (A. Cooperrider, unpub. comp.). Beyond this, knowledge of the redwoods fauna is surprisingly limited. Despite the enormous public attention that has been focused on redwood forests in recent years, comparatively little has been written about the ecology of their terrestrial fauna. One explanation for this deficiency is that few animal species are endemic to the redwood region and no known species is restricted to redwood stands. Although the biogeography of redwood forests and associated fauna has not been well studied, the evidence suggests that most vertebrate species opportunistically adapted to life in the redwoods relatively recently, rather than having coevolved with redwoods over a long period of geologic time. Vertebrate species lists from redwood and Douglas-fir forests in the redwood region show few differences (table 5.1), with a nearly 95 percent

Author contributions: Cooperrider, lead writer and organizer; Noss, writing and editing throughout; Welsh, amphibians and reptiles; Carroll and Zielinski, forest carnivores; Olson, invertebrates; Nelson, marbled murrelet; Marcot, editing throughout and contribution to table on endemics.

and the large cedar borer *(Semanotus ligneus sequoiae)* have been recorded exclusively from coast redwoods (Snyder 1992). Although few invertebrates are known to feed directly on redwoods, many species are associated with the moss, fern, lichen, and other epiphyte mats that cover the branches of mature redwoods (see chap. 3).

The ecological interactions of temperate rain-forest invertebrates can be complex, with many linkages to other processes and species. For example, the ferocious folding-trap-door spider (*Antrodiaetus pugnax*) occurs at high densities in old-growth forests and is thought to regulate populations of numerous invertebrate prey species (Coyle 1971). The handsome iridescent fly (*Eulonchus tristis*) is one of the most important pollinators of understory plants (i.e., native bees avoid shade), but its reproductive success is dependent on the availability of *Antrodiaetus* as hosts for its young (Lattin and Moldenke 1992).

Conservation of Invertebrates

The biota of late-seral redwood forests is sensitive to anthropogenic disturbances such as logging. The loss of large trees over extensive areas eliminates habitat for canopy invertebrates and creates desiccation stress, higher temperatures, and disturbed soil and litter habitats for forest-floor species (Olson 1992; Hoekstra et al. 1995). Selective logging of redwood forests can significantly alter guild structure, abundance; and diversity of invertebrates for long periods of time (Hoekstra et al. 1995)-predisturbance species composition may be absent even fifteen years after logging. Heavy logging of redwoods, and old-growth forests in general, causes the loss of large trees and complex microhabitats, disturbance of soil and litter habitats, loss of coarse woody debris, and substantial alteration of temperature and moisture regimes; it can also promote the invasion of alien species (Olson 1992; Frest and Johannes 1993). All of these trends seriously affect the native invertebrate biota associated with old-growth redwood forests. Flightless and mesophilic (moisture-loving) species are particularly sensitive to the loss of forest canopies and fragmentation of forests (Main 1987; Moldenke and Lattin 1990b; Olson 1992; Lattin 1993; Winchester and Ring 1996a; Winchester 1997).

The diversity and abundance of old-growth invertebrates may be irreversibly changed if logging is extensive and source populations are eliminated across the landscape (Vlug and Borden 1973; Schowalter 1990; Frest and Johannes 1993; Winchester and Ring 1996a; Winchester 1997). If many invertebrate species are restricted to local areas-and strong evidence suggests this-then the loss of more than 95 percent of the original redwood forest (U.S. Fish and Wildlife Service 1997) has almost certainly led to numerous extinctions of old-growth redwood invertebrates. A better understanding of patterns of invertebrate beta diversity (species turnover along environmental gradients), microhabitat specificity, and local endemism is urgently needed for conservation planning

(see Olson 1992; Samways 1994; Winchester 1993, 1997; Winchester and Ring 1996a).

Forest Carnivores of the Redwoods Region

Forest carnivores (forest-dwelling mammals of the order Carnivora) merit conservation concern for their functional importance to ecosystems and for what they indicate about ecosystem condition. Carnivores affect the behavior and demography of their prey, cycle nutrients by scavenging carrion, complete or interrupt pathogen and parasite life cycles, and affect plant distribution-and likely landscape pattern-through dispersal and predation of seeds (Buskirk in press). Mammalian carnivores affect human economies and cultures positively (e.g., tourism generated by the spiritual and aesthetic value of observing them, harvest of some commercially important species) and negatively (e.g., depredations on livestock and fish at hatcheries, transmission of rabies). The population status of carnivores is a measure of ecosystem condition and integrity (Noss et al. 1996); maintaining and restoring their diversity, natural distributions, and abundances have ecological, spiritual, and economic value.

Historical Distributions and Abundances

An obvious yardstick by which to evaluate the status of mammalian carnivores in the redwood region is to compare their current diversity, distribution, and abundances to what they were before intensive human activities (i.e., settlement by Europeans). Unfortunately, little is known about the wildlife of the region prior to the twentieth century. The traditional uses of furbearing mammals by Native Americans-some of which are still practiced today-and the accounts by anthropologists of the customs of tribes of the region (e.g. Scott and Kroeber 1942), provide some insight on the diversity and abundance of mammalian carnivores. Most notable are the species that were either a potential threat to human life (i.e., grizzly bears) or which had important spiritual or cultural value. Grizzly bears appear to have been common throughout the region, especially along the mouths of the major rivers. Early historical information on smaller carnivores is reflected in the ceremonial use of their skins in regalia. The Hupa (Hoopa) tribe has existed on the eastern margin of the redwood region since before recorded history; their regalia include the skins of bobcat, fox, fisher, and ringtail (B. Colegrove, pers. comm.). Some species (e.g., marten and wolverine) are conspicuous by their absence in regalia, which may signify either they did not occur in the region or were extremely rare. Early European explorers and settlers left little recorded history of the wildlife of the redwood region. The Spanish, in the late 1700s, and then the Russians and Americans in the 1800s, focused their wildlife harvesting activities just offshore, on the California sea otter, whose pelt exceeded the value of any terrestrial furbearer.

The earliest scientific account of the ecology, distribution, and status of mammalian carnivores in California is a summary by Joseph Grinnell, Joseph Dixon, and jean Lindsdale of trapping records, interviews, and field observations during the first decades of the twentieth century (Grinnell et al. 1937). They reported eighteen species of terrestrial mammalian carnivores as suspected to have occurred in the redwood region: two ursids, two procyonids, ten mustelids, two canids, and two felids (table 5.5). They ranged in size from the short-tailed weasel (ermine), at less than 1 kg, to the 650-kg grizzly bear, and can be categorized into

Table 5.5. Mammalian Carnivores That Historically Occurred in the Redwood Region, Their Typical Habitat in the Region, Their Status in the Region in the 1920s, and Their Current Status.

Species	*Habitat*	*Status in 1920s*	*Status Today*
Grizzly bear (*Ursus arctos*)	Generalist; grasslands, bays, forests, and mouths of major rivers	Extirpated but formerly common	Extirpated
Black bear (*Ursus americanus*)	Forests at all elevations	"Plentiful"	Regulated game species; limited season and bag limit; perhaps more abundant since ex tirpation of grizzly; commonly detected at track plate stations
Raccoon (*Procyon lotor*)	Lowlands and streamcourses in foothills and lower margins of fir forests; semi-aquatic	Moderate decline due to wetland drainage	Regulated fur-bear ing game species; still common along streamcourses and near human habi tation
Ringtail (*Bassariscus astutus*)	Open, deciduous forests on ridges and near streamcourses	`quite plentiful, espe-cially in northwestern California'	Protected from trapping or hunt ing; more common at track plate sta tions in interior forests than in red-woods along the coast
Long-tailed weasel (*Mustela frenata*)	Habitat generalist; forest/grassland edges	Not specified	Unprotected non game species; no closed season and no limit; uncom monly detected at track plate stations

Species	*Habitat*	*Status in 1920s*	*Status Today*
Short-tailed weasel (*Mustela erminea*)	Grasslands/meadows, especially at higher elevations	Not specified limit; uncommonly detected at track plate stations	Unprotected non game species; no closed season and no bag
Mink (*Mustela vison*)	Aquatic; marshes along bays and mouths of rivers and along mountain streams; found away from water more along north coast than else where in California	Moderate decline due to wetland drainage	Regulated fur-bearing game species; limited season but no bag limit
Marten (*Martes americana*)	Mature redwood forests and on higher ridges of Douglas-fir	`Sparse occurrence, though previously fairly numerous'	Protected; California Species of Special Concern; two *individuals* verified within the redwood range in past 50 years
Fisher (*Martes pennanti*)	Mature mixed coniferous and deciduous forests at all elevations but most common in mountains	Is becoming more rare, `probably less than 300 in entire state'	Protected; California Species of Special Concern; twice petitioned to be listed under federal Endangered Species Act; commonly detected at trackplate stations in the redwood zone but less so than in interior coast ranges
Wolverine (*Gulo gulo*)	Unconfirmed, high-elevation forests suspected	Extinct, "formerly suspected to occur in the mountainsof the northem coast region"	Protected; California Threatened Species; sporadic unconfirmed sightings
Otter (*Lutra canadensis*)	Aquatic; marshes along bays and mouths of rivers and in mountain streams	"Numbers are stable and the species is expected to persist"	Protected
Spotted skunk (*Spilogale gracilis*)	Drier forests and upland rocky or brushy unforested areas ,	"Population has maintained itself rather consistently"	Unprotected non-game species; no closed season and no bag limit; commonly detected at track plate stations
Striped skunk (*Mephitis mephitis*)	Brushy woodlands at low elevation, regions with sod-forming vegetation, beaches	"The most abundant of the fur-bearing mammals"	Unprotected non game species; no closed season and no bag limit

(*continues*)

Table 5.5. (continued)

Species	*Habitat*	*Status in 1920s*	*Status Today*
Badger (*Taxidae taxus*)	Open, unforested regions and forests interspersed with grasslands	"Numbers but little reduced from those of former times"	Regulated fur-bearing game species; limited season but no bag limit
Gray fox (*Urocyon cinereoargenteus*)	Brushy woodlands and forest from sea level to high-elevation forests.	"Trapping has caused relatively little change in numbers"	Regulated fur-bearing game species; limited season but no bag limit
Coyote (*Canis latrans*)	Brushy woodlands and forest from sea level to high-elevation forests; openings caused by timber harvest	Recent immigrant to north coast region; numbers increasing	Unprotected nongame species; no closed season and no bag limit
Wolf (*Canis lupus*)	Unknown wood region.	Unconfirmed in red-	Protected
Mountain lion (*Puma concolor*)	Habitat generalist; forests, woodlands and brush at all elevations	"Breeding stock has not been greatly reduced"	Protected
Bobcat (*Felis rufus*)	Habitat generalist; forests and brushlands with rocky ground, river bottoms	"Wide distribution would be last fur animal to become extinct in California"	Regulated fur-bearing game species; limited season and bag limit; relatively commonly detected at track plate stations

Source: Grinnell et al. (1937).

six groups by habitat: aquatic or semiaquatic species (otter, mink), riparian associates (raccoon, ringtail), habitat generalists (grizzly bear, black bear, coyote, mountain lion), forest generalists (gray fox, spotted skunk, bobcat, long-tailed weasel), grassland/meadow associates (striped skunk, short-tailed weasel, badger), and mature forest associates (marten, fisher, wolverine).

Only one species of mammalian carnivore, the American marten, includes a recognized subspecies that is considered endemic to the humid redwood belt. The Humboldt marten (*M. a. humboldtensis*) is distinguished from the other California subspecies, *M. a. sierrae*, by its darker color, reduced size of orange throat patch, and various cranial skeletal features (Grinnell and Dixon 1926; Grinnell et al. 1937). Genetic analysis to establish the genetic uniqueness of this subspecies is under way (Bayliss and Zielinski, in prep.).

Although the classic work by Grinnell et al. is the most extensive summary of

the ecology of mammalian carnivores of California, by the time it was undertaken, the trapping and hunting of terrestrial furbearers had already begun to decimate their populations: "Since the State was first occupied by white man, the major population trends of fur animals has been downward" (Grinnell et al. 1937:24). The grizzly was extirpated from the redwood region by the mid-1800s, the wolverine was absent and suspected to have been extirpated, and the marten and fisher were undergoing significant population declines in the early twentieth century. The decline of some species apparently occurred so soon after European colonization that it is unclear whether they ever occurred in the region. No documentation exists of the historic occurrence of wolverine or wolf in the redwood region. The wolverine was suspected to have occurred in the "mountains of the northern coast region" (Stephens 1906, cited in Grinnell et al. 1937), but this could not be verified. And of the wolf, Grinnell et al. stated, "If the northwest timber wolf ever occurred in California, which is not unlikely, it probably was restricted to the northwest coastal strip of high humidity and heavy timber." Thus, historical information provides little basis for interpreting the current apparent absence of wolverines and wolves in northwestern California.

Early Conservation Efforts

By the end of the nineteenth century, the reduction in numbers of fur-bearing mammals had become so great that the "attention of thoughtful people was directed to it" (Grinnell et al. 1937). Laws were enacted in 1913 to protect the sea otter and in 1917 to set seasonal and bag limits on the take of several species of terrestrial carnivores. By the 1920s, it was clear that species with high market value-the marten, fisher, and wolverine-would require special conservation efforts (Dixon 1924), a plea that was reinforced in the 1940s (Twining and Hensley 1947). The marten was protected from trapping in 1946 in northwestern California, and the fisher season was closed statewide in the same year.

The protection of vulnerable species from commercial trapping in the mid-1900s was a pivotal conservation measure. Nevertheless, government trappers continued to trap and poison carnivores in the interest of protecting livestock. In four counties in California (including Humboldt Co.), from 1920 to 1930, government predator control agents killed an estimated 40,000 carnivores, rare forest carnivores such as fisher and marten no doubt among them.

Although targeted trapping of forest carnivores was now regulated, the second major threat to forest-dwelling mammals-timber harvest-was intensifying in the redwood region in the mid-1900s (see chap. 2). Most vulnerable are the species associated with old forests-marten and fisher. These species are typically associated with mature, mesic forests, noted for their structural complexity (uneven aged with high densities of snags and logs), large-diameter trees for resting and denning, and closed canopies (Buskirk and Ruggiero 1994; Powell

and Zielinski 1994). Clear-cutting has been the dominant silvicultural method for the harvest and regeneration of redwood (see chap. 8) and is the greatest current threat to the recovery and conservation of forest carnivores.

Current Status o f Carnivores

The end of the twentieth century brings renewed interest in the status of carnivores. Although the threat of trapping-at least to those species most vulnerable-has abated, most of the original redwood forest to which carnivores were adapted has been forever changed. With adequate habitat and source populations, protection from trapping usually leads to the restoration of furbearer populations (Coulter 1960; Buskirk 1993). The quality of the habitat in the redwood zone, however, has apparently declined since the fisher and marten were protected in the 1940s. The offsetting effects of protection from trapping and increasing habitat loss can be evaluated by examining the current diversity, distribution, and relative abundance of carnivores.

Since the late 1980s, carnivore surveys using standard detection methods (Zielinski and Kucera 1995) have been conducted with increasing frequency. Most surveys have been conducted in the northern redwood zone; areas south of Humboldt County have received little effort, and regions south of San Francisco Bay virtually none. The most comprehensive surveys in redwoods have been those by Klug (1996) and Beyer and Golightly (1995), but the results of other surveys conducted by timber companies, the USDA Forest Service, and environmental consulting companies have produced similar results. Considering the entire redwood region, including both redwood-dominated areas and those with substantial coverage of other tree species, the most commonly detected species are the gray fox, spotted skunk, bear, and fisher. Next most frequently detected are the raccoon, bobcat, and ringtail, with detections of weasel (*Mustela erminea* and *M. frenata* cannot be distinguished by their tracks) and striped skunk the least frequent. Each species has characteristics that place it on a continuum from relatively easy to very difficult to detect using enclosed track plate methods. Several of the most frequently detected species appear to have a low threshold for entering and re-entering track plate enclosures. Other species, such as the coyote, which appears to avoid novel items associated with humans, and the bobcat, which like many cats does not regularly consume carrion, are less effectively detected using these methods. For this reason, and due to the varying densities and home range sizes of the species, the number of detections is not a reliable index of relative abundance. For those species that regularly visit baited track plates, however, detections are a reliable measure of presence.

Survey results are somewhat different considering only redwood-dominated stands. Fishers are less common in redwood-dominated stands than in mixed redwood-Douglas-fir or Douglas-fir dominated forests that occur farther inland (Beyer and Golightly 1995; Klug 1997). Ringtails also appear less common in

the redwood-dominated stands. Black bear, gray fox, and spotted skunk are again the most commonly detected carnivores in redwood forests.

In reviewing surveys in the northern redwood zone over the past ten years, the most disturbing conclusion is the absence of the Humboldt marten. Since 1990, more than 1,000 track plate or camera stations have been deployed in more than 15,000 survey days without a single marten detection (Zielinski and Golightly 1996). This finding is especially noteworthy because martens are one of the species most readily attracted to and detected at track plate stations (Kucera et al. 1995; Zielinski et al. 1997).

Moreover, fisher researchers or commercial trappers seeking legal quarry have not trapped marten incidentally, nor has a single road killed marten been reported to any state or federal resource agency in the redwood zone (Zielinski and Golightly 1996). Recently, marten have been detected at two locations near the eastern limit of the subspecies' original range, 20 km apart, during surveys conducted in Douglas-fir forests (Zielinski, unpubl. data.). Although these are the first martens verified within the historic range of the Humboldt subspecies, their genetic relationship to the martens that once occurred in the low-elevation redwood forests has yet to be established. Even considering these recent detections, the prognosis for the natural recovery of marten in the redwood forest is poor.

Consequences o f Logging for Forest Carnivores

The absence of verified records of wolverine in the redwood region and the loss of marten as a common predator in redwood ecosystems means that little local information is available on their habitat requirements. For marten, we can surmise the effects of ,logging based on their responses elsewhere, but the lack of data from the Pacific states makes this difficult for wolverines. Hence, most of our discussion must focus on the fisher, the only species of forest carnivore that remains in sufficient numbers to be the subject of recent research.

Almost everywhere they occur in the western United States, and like martens, fishers are associated with extensive, structurally complex, late-seral forests (Rosenberg and Raphael 1988; Buskirk and Ruggiero 1994; Powell and Zielinski 1994). Patterns of habitat association in wide-ranging carnivores, like many other species, are complex because of the interaction of processes operating at multiple scales. For example, detections of fishers in second-growth redwood stands belie a simplistic characterization of the species as an old-growth associate (Harris 1984). Though younger stands may retain habitat value at the patch scale (see discussion on WHR in the preceding section), landscape and regional-scale changes in redwood ecosystems give reason for concern about the long-term viability of coastal fisher populations--and the recovery of marten--under current timber-harvesting regimes.

Stand-level changes in redwood habitat likely to affect forest carnivores include reduction in canopy closure, tree diameter, and snag and log abundance,

as well as changes in floristic composition. High levels of overhead cover provide protection from predation, lower the energetic costs of traveling between foraging sites, and provide more favorable microclimatic conditions (Powell and Zielinski 1994; Buskirk and Ruggiero 1994; Thompson and Harestad 1994). Abundance or vulnerability of preferred prey species may be higher in areas with higher canopy closure (Buskirk and Powell 1994) or coarse woody debris. Clear-cutting, or any logging that reduces the density of large trees, affects the availability of denning and resting sites and structural components associated with prey vulnerability (Thompson 1986; Thompson and Colgan 1987; Thompson and Harestad 1994; Sturtevant and Bissonette 1997). Runoff from clear-cut sites also can severely degrade riparian areas, which not only are essential habitat for aquatic and semiaquatic carnivores but also provide critical foraging, travel, and resting habitats for marten and fisher (Powell and Zielinski 1994).

Changes in species composition associated with logging may include an increase in hardwood species (red alder and tanoak) and Douglas-fir. These floristic changes may have favored the expansion of fishers in the redwood region at the expense of martens, which are more closely associated with conifer than mixed forests. Marten have been shown elsewhere to suffer from competition with fishers, especially in regions lacking deep snow (Krohn et al. 1995). The lack of snow throughout most of the redwood zone, which if deep enough would inhibit fisher movement more than marten, may be an impediment to the recolonization of marten in regions where fishers are common.

Several structural features may enhance the resiliency of redwood forest to disturbance from logging. Regeneration by basal sprouting allows stands to recover canopy closure more quickly than in trees that regenerate from seed (seechap. 4). Historical logging methods often left behind coarse woody debris, snags, and residual "wolf" trees that provide a structural "legacy" that are favored rest sites for fishers (R Klug, pers. comm.). Current harvesting methods are more intensive, however, and as harvested redwood stands enter short-term rotations they will increasingly lack the structural and floristic complexity they possessed before harvest (see chap. 8).

Changes in landscape patterns in the redwood region, such as the fragmentation described earlier, may limit the positive effects of stand-level resiliency. The current landscape mosaic in the redwood zone differs in several respects from the pre-settlement condition. Historically, redwood stands formed a mosaic with other forest types, such as oak woodland and closed-cone conifer forest, with fire playing a significant role (see chap. 3 and 4). The current landscape condition shows a lower abundance of older stands, smaller patch size, lower spatial and temporal variability in stand age-class distribution, and reduced natural fire frequency. These trends are likely to lead to reduced functional connectivity for species associated with older forests, as has been shown elsewhere for American marten (Hargis and Bissonette 1997).

Increased road access is often suggested as a negative collateral effect of logging primary forest. Roads provide access for trappers and are a source of vehicle-caused mortality. None of the rare forest carnivores is currently legally trapped, but they are captured incidentally in traps set for other species (Lewis and Zielinski 1996), and roadkills are not uncommon. Analyzing the effect of road density on abundance and distribution is difficult, however. For example, if productive forestlands are preferentially targeted for logging and associated road-building, a complex interaction of road density and habitat quality may be evident. Fisher detections were positively correlated with low-use road density in the eastern Klamath region, but this conclusion is difficult to interpret in light of the absence of a negative effect of high-use roads (Dark 1997). Perhaps because of the scarcity of primary forest in the redwood region, older second-growth forest with low to moderate road density probably is a critical factor as forest carnivore habitat.

Habitat Value o f Redwoods for Forest Carnivores

Klug's (1996) extensive surveys for fishers in the redwood zone found positive correlations between fisher detection rates and such stand-level attributes as diameter and basal area of hardwoods, canopy closure, and volume of logs. Similarly, Carroll et al. (1999), using survey data from the adjacent inland forest types, found fisher detection rates were highest at sites with large hardwoods in landscapes of dense, mixed hardwood-conifer forests.

Lower detection rates for fishers in redwood forests when compared to the redwood-Douglas-fir transition zone led Klug (1996) to conclude that redwood habitat supported smaller populations. The generality of this conclusion may be limited, however, by the predominantly early-seral character of the commercial timberlands surveyed in Mug's study. The habitat model of Carroll et al. (1999) predicts greater variability of detection rates in the redwood forest, in part because of the high contrast in average tree age and diameter between protected areas and commercial timber lands. Beyer and Golightly (1995) report generally lower than expected detection rates in redwoods; they note, however, that a survey transect in Redwood National Park recorded high detection rates. Although floristic variation, especially the abundance of large hardwoods, appears to be a major factor influencing fisher distribution, the relative habitat value of late-seral redwood stands cannot be characterized without additional surveys.

Regional-scale variation in fisher abundance confounds efforts to unravel stand-level habitat associations. Biogeographic correlations between fisher distribution and such regional factors as elevation and distance to the ocean (Klug 1996) or precipitation and geographic variables (Carroll 1997) may be as strong as those with patch or landscape-level habitat attributes. The higher detection rates in Redwood National Park as compared to Humboldt State Redwoods

Park (Beyer and Golightly 1995) and the low rate of detections on commercial timberlands in the north and south of Klug's (1996) study area may reflect these regional-scale factors.

One hypothesis links the coarse-scale distribution patterns described above to regional fisher metapopulation structure (Carroll et al. 1999). The concept of a metapopulation of populations linked by occasional dispersal may be especially applicable to fishers inhabiting the fragmented habitat of the redwood region. We use the term metapopulation in a broad sense here, as real-world metapopulations often do not conform to the classic "island-island" model (Harrison 1994). Instead, "Central patches are united by dispersal into a single population, slightly more isolated ones undergo extinction and recolonization, and still more isolated patches are usually vacant" (Harrison and Taylor 1997). Limited evidence concerning the structure of the regional fisher metapopulation suggests that the lower Trinity River watershed may function as a central "mainland" population. This pattern would favor occupation by fishers of redwood forest lying to the west of this area.

As with the spotted owl, fisher metapopulations may show nonlinear responses to the size and spacing of habitat clusters. If clusters of suitable habitat become too small or isolated, the imbalance between immigration and emigration can limit long-term viability (McKelvey et al. 1993 Noon and McKelvey 1996). The decline in distribution of the fisher in the western United States may be due to such regional-level dynamics (Heinemeyer and Jones 1994). Existing land management planning processes are poorly adapted to decision-making across administrative boundaries. A comprehensive plan to ensure the viability of forest carnivores and maintain well-distributed populations would need to include measures to increase levels of canopy closure on managed lands and restore connectivity through development of landscape linkages between the redwood parks and stands farther inland. The survival of the fisher and marten, like that of other wide-ranging carnivores, may ultimately depend on multiownership cooperative management on a regional scale (Mladenoff et al. 1995).

Marbled Murrelets in Redwoods

The marbled murrelet is a seabird that nests up to 88 km inland in coastal, older-aged coniferous forests throughout most of its range from Alaska to central California. Murrelets fly at high speeds (up to 158 km/h), attend their breeding sites primarily during low light levels, and nest solitarily (Nelson and Hamer 1995a; Nelson 1997). The secretive aspects of their breeding biology have made their nests difficult to locate; the first murrelet nest was not discovered until 1974 (Big Basin State Park, California; Binford et al. 1975). Since then, more than 170 nests have been found, 18 of them in California (table 5.6).

Table 5.6. Characteristics of Marbled Murrelet Tree Nests in California.

Site	*Tree species*[a]	*Diameter (dbh, cm)*	*Tree height (m)*	*Limb height (m)*	*Limb diameter at bole (cm)*	*Limb diameter from nest* (cm)	*Distance from trunk* (cm)	*Vertical cover* (%)	*Moss depth (mm)*	*Moss* (%)	*Outcome/ stage*[b]
Big Basin State Park 1974[c],	PSME	167.0	61.0	45.0	41.0	-	6.8	100	0.8	100	failed/chick fell out
Big Basin State , Park 1989[d]	PSME	210.0	61.2	43.7	-	47.7	122.0	100	1.0	100	predation by CORA / egg
Big Basin State Park 1989[d]	PSME	196.0	76.2	38.5	-	36.3	61.0	100	1.0	100	predation by STJA / chick
Big Basin State Park 1991[e]	SESE	533.0	79.2	41.1	61.0	61.0	0	100	0	0	successful
Big Basin State Park 1992[e]	SESE	533.0	79.2	53.2	42.0	42.0	0	100	0	0	successful
Pacific Lumber 1992[f]	SESE	229.0	86.5	67.0	21.2	21.0	0	100	0	0	failed/chick died
Pacific Lumber 1992[f]	SESE	254.0	74.3	67.5	25.0	20.0	18.0	100	0	0	unknown
Pacific Lumber 1993[g]	PSME	183.0	70.0	37.0	37.0	30.0	0	5	3.8	100	inactive
Pacific Lumber 1993[g]	SESE	300.0	83.0	60.0	37.0	37.0	5.0	50	0	5	unknown
Jedediah Smith State Park 1993[h]	SESE	338.0	79.5	43.6	21.0	16.0	90.0	99	0	1	inactive
Prairie Creek State Park 1993[h]	TSHE	139.0	66.7	33.3	29.0	23.0	20.0	98	8.1	100	inactive
Big Basin State Park 1994[e]	SESE	533.0	79.2	41.1	61.0	61.0	0	100	0	0	predation/egg
Butano State Park 1995[i]											predation by CORA / egg

(*continues*)

Table 5.6. (*continued*)

Site	*Tree species*[a]	*Diameter (dbh, cm)*	*Tree height (m)*	*Limb height (m)*	*Limb diameter at bole (cm)*	*Limb diameter from nest (cm)*	*Distance from trunk (cm)*	*Vertical cover (%)*	*Moss depth (mm)*	*Moss (%)*	*Outcome/ stage*[b]
Big Basin State Park 1996[j]	SESE	533.0	79.2	53.2	42.0	42.0	0	100	0	0	predation/egg
Big Basin State Park 1996[j]	SESE	174.0	48.8	31.7	18.0	18.0	0	80	0	0	successful
Big Creek Lumber predation/chick 1997[k]											
Pescadero Creek County Park 1997[k]											predation by RSHA/egg unknown
Overall (mean + SE)		308.7 + 41.7	73.1 + 2.8	46.9 + 3.1	36.3 + 4.2	35.0 + 4.3	23.1 + 10.5	88.0 + 7.4	1.1 + 0.6	36.1 + 13.2	

[a] PSME - *Pseudotsuga menziesii*, SESE - *Sequoia sempervirens*, TSHE = *Tsuga heterophylla*
[b] CORA = Common Raven, STJA = Steller's Jay, RSHA = Red-shouldered Hawk
[c] Binford et al. 1975
[d] Singer et al. 1991
[e] Singer et al. 1995
[f] Kerns and Miller 1995
[g] S. Chinnici, pers. comm.
[h] T Hamer, pers. comm.
[i] D. Suddjian, pers. comm.
[j] S. W Singer, pers. comm.
[k] E. Burkett, pers. comm.

Murrelet nests in California, like other tree nests throughout their range (Hamer and Nelson 1995), occur in large, tall redwood, Douglas-fir and western hemlock trees (table 5.6). These nests are located above the 30 m height on large limbs with high vertical cover. In contrast to other regions, nest limbs in California generally have less moss because of drier conditions and higher daytime temperatures compared to farther north. Key components of nesting habitat in California include the percentage of old-growth canopy cover and tree species composition (>50 percent coast redwood; Miller and Ralph 1995). The amount of habitat along major drainages and at lower elevations is also useful in predicting murrelet occurrence.

Marbled murrelets in California are known to occur primarily in the coast redwood forests. Only a few observations (but no nests) have been recorded in Douglas-fir dominated forests. The distribution of redwood forests closely matches the inland extent of marine air influences and summer fog (Barbour and Major 1988; and see chap. 3 and 4). At sites farther inland, where the maritime influence is limited by rugged topography, Douglas-fir and tanoak forest types dominate. Although these forests generally have multiple tree layers, large trees, and potential nesting platforms (Jimerson et al. 1996), summer temperatures are higher, resulting in a lack of moss on tree limbs and hot, dry conditions that may be unsuitable for nesting by murrelets. The distance to the ocean is also greater, increasing energetic demands.

Murrelet nests are frequently unsuccessful; overall nest success has been only 37 percent (n = 60; Nelson and Hamer 1995b; S. K. Nelson and I. A. Manley, unpub. data). Of the twelve nests with known outcomes in California, 75 percent (n = 9) were unsuccessful (table 5.6). Of those that failed, seven (78 percent) failed from predation during the egg (n = 5) and chick (n = 2) stages. Known predators at these nests have included common ravens, Steller's jays, and red-shouldered hawks. Habitat fragmentation (smaller stand size, more edge habitat) and distance of nests from the tree trunk and stand edge (roads, clearcuts, younger forests) are factors that appear to reduce nest success (Nelson and Hamer 1995b; S. K. Nelson and I. A. Manley, unpub. data).

An estimated 60,000 or more marbled murrelets were found historically along the coast of California (Larson 1991); today, only about 6,000 birds (including breeders and nonbreeders) remain (Ralph and Miller 1995)--a 90 percent decline. Murrelet populations are projected to be declining at a rate of 4-7 percent per year (Beissinger 1995), primarily because of habitat loss and fragmentation from logging and development. This species was federally listed as threatened in Washington, Oregon, and California (U.S. Fish and Wildlife Service 1992) and state listed in California as endangered (California Fish and Game Commission 1992) in 1992.

Less than 4 percent of the original redwood forests, once totaling more than 770,000 ha, remain in California (U.S. Fish and Wildlife Service 1997).

Suitable marbled murrelet forest habitat currently occurs in three separate areas: (1) Humboldt, (2) Del Norte Counties in the north, and (3) San Mateo and Santa Cruz counties in central California; the northern and central areas are separated by a distance of about 480 km, as most of Mendocino County no longer contains nesting habitat. Most of the remaining redwood forests occur in state, county, and national parks; however, more than 36,000 ha apparently remain on private land, especially in Humboldt County. In California, critical murrelet habitat (i.e., critical for species survival) was designated primarily on federal land (64 percent; 193,150 ha). Nevertheless, 88,750 ha on state and county lands and 18,080 ha of private forests were also designated as critical because habitat protected in parks and national forests alone will not guarantee the long-term survival of the murrelet (U.S. Fish and Wildlife Service 1996). Most of the private critical habitat occurs on lands owned by the Pacific Lumber Company, which are currently the subject of a multispecies habitat conservation plan (HCP) under section 10(a) of the federal Endangered Species Act. Approved just before this book went to press, this HCP would allow some incidental take of murrelets and, many feel, does not replace the old-growth forest structure required by murrelets.

In the Marbled Murrelet Recovery Plan (U.S. Fish and Wildlife 1997), goals for recovery call for preventing the loss of any additional occupied habitat. Developing new habitat and improving the quality of existing habitat by minimizing human impacts in the parks is also recommended to ensure the long-term survival of this species. In California and elsewhere, however, many private timber companies are currently negotiating HCPs with the U.S. Fish and Wildlife Service that would allow them to log some occupied and critical habitat and cause "incidental take" of murrelets. These negotiations, under the auspices of section 10(a) of the federal Endangered Species Act, are likely to cause a continual decline in suitable murrelet habitat. The next fifty years have been identified as the most critical for murrelets, a time period in which, under the Northwest Forest Plan (U.S. Departments of Agriculture and Interior 1993), some habitat on federal lands will become suitable for nesting by murrelets. The current downward trend of available murrelet nesting habitat, however, along with pressures on their food resources from El Nino and overfishing, and adult mortality in oil spills and the gill-net fishery, place the continued survival of this seabird in jeopardy.

Conclusions

The fauna of the redwood forest and region, though poorly known compared to many forest regions, reflects the long evolutionary history of the redwood lineage and the relative stability of this forest over millennia. Many of the animals of the region are adapted to moist, intact forest distributed over large areas and

to the structural characteristics of late-seral forest, ranging from the coarse woody debris on the forest floor to the complex canopies 100 m above the ground. Although they occurred in a mosaic with many other kinds of vegetation, old-growth redwood forests dominated the region for a long period of time before settlement by Europeans. The redwood fauna reflects this antiquity.

The drastic diminishment of old-growth redwood forests in the span of just several human generations threatens many forest species with extinction. The reduction in total area of old-growth redwoods is only part of the problem-just as threatening to many species is the continued simplification of the structure of these forests and their fragmentation into smaller, more isolated pieces. Undoubtedly, some species of invertebrates have been lost before they were ever described by science, and some vertebrates (i.e., several amphibians, Humboldt marten, fisher, northern spotted owl, and marbeled murrelet) are seriously imperiled. Although no species or subspecies is strictly endemic to the redwood forest, several are endemic to the region, and the long-term persistence of many more likely depends on conservation actions taken here.

THE REDWOOD FOREST

History, Ecology, and Conservation of the Coast Redwoods

Edited by
Reed F. Noss

Save-the-Redwoods League

ISLAND PRESS
Washington, D.C. • Covelo, California

Literature Cited

Barbour, M. G., and J. Major. 1988. *Terrestrial vegetation of California.* New York, NY: John Wiley and Sons.

Beyer, K. M., and R. T. Golightly. 1995. Distribution of Pacific fisher and other forest carnivores in coastal northwestern California. California Department of Fish and Game. Unpublished Report, Sacrament, CA.

Beissinger, S. R. 1995. Population trends of the marbled murrelet projected from demographic analyses. Pp. 385-393 in C. J. Ralph, G. L. Hunt Jr., J. F. Piatt, and M. G. Raphael, eds., *Ecology and conservation of the marbled murrelet.* General Technical Report PSW-GTR-152. Albany, CA: USDA Forest Service.

Binford, L. C., B. G. Elliott, and S. W. Singer. 1975. Discovery of a nest and the downy young of the marbled murrelet. *Wilson Bulletin* 87:303-319.

Buskirk, S. W. 1993. The refugium concept and the conservation of forest carnivores. Pp. 242-245 in I. D. Thompson, ed., *Proceedings of the International Union of Game Biologists XXI Congress, Forest and wildlife towards the 21st century.* August 15-20, 1993. Halifax, Nova Scotia.

_____. In press. Mesocarnivores of Yellowstone. In T. W. Clark, S. C. Minta, P. K. Karieva, and A. P. Curlee, eds., *Carnivores in ecosystems.*

Buskirk, S. W., and R. A. Powell. 1994. Habitat ecology of fishers and American marten. Pp. 283-296 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R. A. Powell, eds., *Marten, sables and fishers: Biology and conservation.* Ithaca, NY: Cornell University Press.

Buskirk, S. W., and L. F. Ruggiero. 1994. American marten. Pp. 38-73 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, tech. Eds., *The scientific basis for conserving forest carnivores, American marten, fisher, lynx, and wolverine in the western United States.* General Technical Report RM-254, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO: USDA Forest Service.

California Fish and Game Commission. 1992. Animal of California declared to be endangered or threatened. Gov. Code Sec. 11346.2, Reg. 92:1-8

Carroll, C. 1997. Predicting the distribution of the fisher (*Martes pennanti*) in northwestern California, U.S.A., using survey data and GIS modeling. M.S. thesis, Oregon State University, Corvallis.

Carroll, C., W. J. Zielinski, and R. F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath region, USA. *Conservation Biology* 13: in press.

Coulter, M. W. 1960. The status and distribution of fisher in Maine. *Journal of Mammalogy* 41:1-9.

Coyle, F. A. 1971. Systematics and natural history of the megalomorph spider genus *antrodiaetus* and related genera. *Bulletin of the Museum of Comparative Zoology* (Harvard) 141:269-402.

Dark, S. J. 1997. A landscape-scale analysis of mammalian carnivore distribution and habitat use by fisher. Master's thesis, Humboldt State University, Arcata, CA.

Dixon, J. 1924. A closed season needed for fisher, marten, and wolverine in California. *California Fish and Game* 23-25. Sacramento, CA: California Dept. of Fish and Game.

Frest, T. J., and E. J. Johannes. 1993. *Molluse species of special concern within the range of the northern spotted owl.* Final Report prepared for the Forest Ecosystem Management Working Group, Pacific Northwest Region. Portland, OR: USDA Forest Service.

Grinnell, J., and J. S. Dixon. 1926. Two new races of the pine marten from the Pacific Coast of North America. *Zoology* 21:411-417.

Grinnell, J., J. S. Dixon, and J. Linsdale. 1937. *Fur-bearing mammals of California: Their natural history, systematic status, and relations to man,* vols. 1 and 2. Berkeley: University of California Press.

Hamer, T. E., and S. K. Nelson. 1995. Characteristics of marbled murrelet nest trees and nesting stand. Pp. 69-82 in C. J. Ralph, G. L. Hunt Jr., J. F. Piatt, and M. G. Raphael, eds., *Ecology and conservation of the marbled murrelet.* General Technical Report PSW-GTR-152. Albany, CA: USDA Forest Service.

Hargis, C. D., and J. A. Bissonette. 1997. Effects of forest fragmentation on populations of American marten in the intermountain west. Pp. 437-451 in G. Proulx, H. N. Bryant, and P. M. Woodard, eds., *Martes: Taxonomy, ecology, techniques, and management.* Edmonton, Alberta: Provincial Museum of Alberta.

Harris, L. D. 1984. *The fragmentation forest: Island biogeography theory and the preservation of biotic diversity.* Chicago, IL: University Chicago Press.

Harrison, S., and A. D. Taylor. 1997. Empirical evidence for metapopulation dynamics: A critical review, in I. Hanski and M. E. Gilpin, eds., *Metapopulation biology: Ecology, genetics and evolution.* New York, NY: Academic Press.

Heinemeyer, K., and J. L. Jones. 1994. *Fisher biology and management in the western United States: A literature review and adaptive management strategy.* Northern Region and Interagency Forest Carnivore Working Group. Missoula, MT: USDA Forest Service.

Hoekstra, J. M., R. T. Bell, A. E. Launer, and D. D. Murphy. 1995. Soil arthropod abundance in coast redwood forest: Effect of selective timber harvest. *Environmental Entomology* 24:246-252.

Jimerson, T. M., E. A. McGee, D. W. Jones, R. J. Svilich, E. Hotalen, G. DeNitto, T. Laurent, J. D. Tenpas, M. E. Smith, K. Hefner-McClelland, and J. Mattison. 1996. *A field guide to the tanoak and the Douglas-fir plant associations in northwestern California.* USDA Forest Service R5-ECOL-TP-009.

Klug, R. R. 1996. Occurrence of Pacific fisher in the redwood zone of northern California and the habitat attributes associated with their detection. Master's thesis, Humboldt State University, Arcata, CA.

Krohn, W. B., K. D. Elowe, and R. B. Boone. 1995. Photographic bait stations. Pp. 25-61 in W. J. Zielinski and T. E. Kucera, tech. Eds., *American marten, fisher, lynx and wolverine: Survey methods for their detection.* General Technical Report PSW-GTR-157, Pacific Southwest Research Station. Albany, CA: USDA Forest Service.

Kucera, T. E., A. M. Soukkala, and W. J. Zielinski. 1995. Photographic bait stations. Pp. 25-61 in W. J. Zielinski and T. R. Kucera, tech. Eds., *American marten, fisher, lynx and wolverine: Survey methods for their detection.* General Technical Report PSW-GTR-157, Pacific Southwest Research Station. Albany, CA: USDA Forest Service.

Larson, C. J. 1991. A status review of the marbled murrelet (*Brachynamphus marmoratus*) in California. Report to the Fish and Game Commission, California Department of Fish and Game, Wildlife Management Division, Sacramento.

Lattin, J. D. 1993. Arthropod diversity and conservation in old-growth forests. *Wings* 15:7-10.

Lattin, J. D., and A. R. Moldenke. 1992. Ecologically sensitive invertebrate taxa of Pacific Northwest old-growth conifer forest. Report prepared for the Northern Spotted Owl Recovery Team, Other species, and Ecosystems Committee.

Lewis, J. C., and W. J. Zielinski. 1996. Historical harvest and incidental capture of fishers in California. Northwest Science 70:291-297.

Main, B. Y. 1987. Persistence of invertebrates in small areas: Case studies of trapdoor spiders in western Australia. Pp. 29-39 in D. A. Saunders, G. W. Arnold, A. A. Burbidge, and A. J. M. Hopkins, eds., *Nature conservation: The role of remnants of native vegetation.* Chipping Norton, NSW, Australia: Surrey Beatty and Sons.

McKelvey, K. S., B. R. Noon, and R. H. Lamberson. 1993. Conservation planning for species occupying fragmented landscapes: The case of the northern spotted owl. Pp. 424-450 in P. M. Karieva, J. G. Kingsolver, and R. B. Huey, comps. eds., *Biotic interactions and global change.* Sunderland, MA: Sinauer.

Miller, S. L., and C. J. Ralph. 1995. Relationships of marbled murrelets with habitat characteristics at inland sites in California. Pp. 205-215 in C. J. Ralph, G. L. Hunt Jr., J. F. Piatt, and M. G. Raphael, eds., *Ecology and conservation of the marbled murrelet.* General Technical Report PSW-GTR-152. Albany, CA: USDA Forest Service.

Mladenoff, D. J., T. A. Sickley, R. G. Haight, and A. P. Wydeven. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. *Conservation Biology* 9:279-294.

Moldenke, A. R., and J. D. Lattin. 1990b. Dispersal characteristics of old-growth soil arthropods: The potential for loss of diversity and biological function. *Northwest Environmental Journal* 6:408-409.

Nelson, S. K. 1997. Marbled murrelet (*Brachynamphus marmonatus*). Pp. 1-32 in A. Poole, and F. Gill, eds., *Birds of North America.* No. 276, The Academy of Natural Sciences, Philadelphia, PA; Washington, DC: The American Ornithologists Union.

Nelson, S. K., and T. E. Hamer. 1995a. Nesting biology and behavior of the marbled murrelet. Pp. 57-68 in C. J. Ralph, G. L. Hunt Jr., J.F. Piatt, and M. G. Raphael, eds., *Ecology and conservation of the marbled murrelet.* General Technical Report PSW-GTR-152. Albany, CA: USDA Forest Service.

_____. 1995b. Nest success and the effects of predation on marbled murrelets. Pp. 89-98 in C. J. Ralph, G. L. Hunt Jr., J. F. Piatt, and M. G. Raphael, eds., *Ecology and conservation of the marbled murrelet.* General Technical Report PSW-GTR-152. Albany, CA: USDA Forest Service.

Noon, B. R., and K. S. McKelvey. 1996. Management of the northern spotted owl: A case history in conservation Biology. *Annual Review of Ecological Systematics* 27:135-162.

Noss, R. F., H. B. Quigley, M. G. Hornocker, T. Merrill, and P. C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. *Conservation Biology* 10:949-963.

Olsen, D. M. 1992. The northern spotted owl conservation strategy: Implications for Pacific Northwest invertebrates and associated ecosystem processes. Final Report prepared for the Northern Spotted Owl EIS Team. USDA Forest Service, Order number 40-04HI-2-1650.

Powell, R. A., W. J. Zielinski. 1994. The fisher. Pp. 38-73 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, tech. Eds., *The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the western United States.* General Technical Report RM-254, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO: USDA Forest Service.

Rosenberg, K. V., and R. G. Raphael. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. Pp. 263-272 in J. Verner, M. L. Morrison, C. J. Ralph, eds., *Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates.* Madison: University of Wisconsin Press.

Ralph, C. J., S. L. Miller. 1995. Offshore population estimates of marbled murrelets in California. Pp. 353-360 in C. J. Ralph, G. L. Hunt Jr., J. F. Piatt, and M. G. Raphael, eds., *Ecology and conservation of the marbled murrelet.* General Technical Report PSW-GTR-152. Albany, CA: USDA Forest Service.

Samways, M. J. 1994. *Insect conservation biology*. London, UK: Chapman and Hall.

Schowalter, T. D. 1990. Invertebrate diversity in old-growth versus regenerating forest. *Northwest Environmental Journal* 6:403-403.

Scott, R., and A. L. Kroeber. 1942. Yurok narratives. *American Archaeology and Ethnology* 35:143-256.

Snyder, J. 1992. The ecology of *Sequoia sempervirens*: An addendum to *On the edge: Nature's last stand for coast redwoods*. Master's thesis, San Jose State University, San Jose, CA.

Stephens, F. 1906. *California mammals.* San Diego, CA: West Coast Publishing Co.

Sturtevant, B. R., and J. A. Bissonette. 1997. Stand structure and microtine abundance in Newfoundland: Implications for marten. Pp. 182-198 in G. Proulx, H. N. Bryant, and P. M. Woodard, eds., *Martes: Taxonomy, ecology, techniques, and management.* Edmonton, Alberta: Provincial Museum of Alberta.

Thompson, I. D. 1986. Diet choice, hunting behaviour, activity patterns and ecological energetics of marten in natural and logged areas. Ph.D. diss., Queen's University, Kingston, Ontario.

Thompson, I. D., and P. W. Colgan. 1987. Numerical responses of martens to a food shortage in northcentral Ontario. *Journal of Wildlife Management* 51:824-835.

Thompson, I. D., and A. S. Harestad. 1994. Effects of logging on American martens with models for habitat management. Pp. 355-367 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R. A. Powell, eds., *Martens, sables and fishers: Biology and conservation.* Ithaca, NY: Cornell Press.

Twining, H., and A. Hensley. 1947. The status of pine martens in California. *California Fish and Game* 33:133-137.

U.S. Departments of Agriculture and Interior. 1993. Forest ecosystem management: An ecological, economic and social assessment. Report for the Forest Ecosystem Management Assessment Team, USDA Forest Service, U.S. Fish and Wildlife Service, National Marine Fisheries Service, National Park Service, Bureau of Land Management, and Environmental Protection Agency. Portland, OR.

U.S. Fish and Wildlife Service. 1992. Endangered and threatened wildlife and plants; determination of threatened status for the Washington, Oregon, and California population of the marbled murrelet. U.S. Fish and Wildlife Service Federal Register 57:45328-45337.

_____. 1996. Endangered and threatened wildlife and plants; final designation of critical habitat for the Marbled murrelet. U.S. Fish and Wildlife Service Federal Register 61:26256-26320.

U.S. Fish and Wildlife Service. 1997. Recovery plan for the marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon and California. Portland, OR: U.S. Fish and Wildlife Service.

Vlug, H., and J. H. Borden. 1973. Soil Acari and Collembola populations affected by logging and slash burning in a coastal British Columbia coniferous forest. *Environmental Entomology* 2:1016-1023.

Winchester, N. N. 1993. Coastal Sitka spruce canopies: Conservation of biodiversity. *Bioline* 11:9-14.

_____. 1997. The arboreal superhighway: Arthropod and landscape dynamics. *Canadian Entomologist* 129:595-599.

Winchester, N. N., and R. A. Ring. 1996a. Centinelan extinctions: Extirpation of northern temperate old-growth rainforest arthropod communities. *Selybana* 17:50-57.

Zielinski, W. J., and R. T. Golightly. 1996. The status of marten in redwoods: Is the Humboldt marten extinct? Pp. 115-119 in John LeBlanc, ed., *Conference on coast red-wood forest ecology and management, June18-20, 1996.* Arcata, CA: Humboldt State University.

Zielinski, W. J., and T. E. Kucera. 1995. *American martens, fisher, lynx, and wolverine: Survey methods for their detection.* General Technical Report PSW-GTR-157. USDA Forest Service, Pacific Southwest Research Station, Albany, CA. 163 p.

Zielinski, W. J., R. L. Truex, C. V. Ogan, and K. Busse. 1997. Detection surveys for fishers and American martens in California, 1989-1994: Summary and interpretations. Pp. 372-392 in G. Proulx, H. N. Bryant, and P. M. Woodard, eds., *Martes: taxonomy, ecology, techniques, and management.* Edmonton, Albert, Canada: Provincial Museum of Alberta.