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**By Steven Self, Sierra Pacific Industries,
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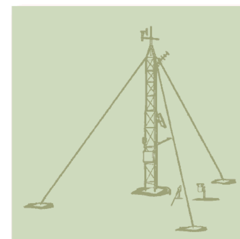

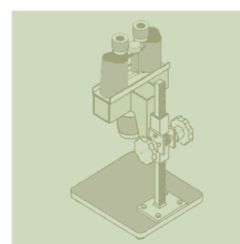

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Introduction

Background

Management strategies to create and maintain forest habitats capable of supporting sustainable populations of native wildlife species have been of interest to timberland managers and wildlife biologists for many decades. Because of the variety of wildlife species that inhabit forested landscapes, it is important to maintain a diversity of habitats. Some wildlife species, such as the pine marten, are considered to be sensitive to forest management activities, and because of this the marten has been designated a "sensitive" species by the USDA Forest Service and a "species of special concern" by the California Department of Fish and Game (CDFG). However, little is known about habitat use by martens in California, and what is known has been conservatively interpreted by government agencies, resulting in management approaches that emphasize reserves and set-aside management systems (USDA 1993; Buskirk and Powell 1994) that take land out of production without in fact demonstrating actual benefits to the pine marten.

Although the majority of habitat types known to support pine marten in California exist on public lands, a significant portion can be found on private forestland (Grinnell et al. 1937). And private landowners need management options that allow them to engage in sustainable forest-product production that is at the same time compatible with the habitat needs of pine marten. In addition, recent and widespread recognition of the increasing threat of catastrophic wildfire to wildlife habitats suggests that other approaches to management of sensitive species habitats should be developed (Verner et al. 1992).

Purpose of Study and Description of Study Area

Sierra Pacific Industries (SPI) manages over 1.5 million acres of forest in Northern California. One of its management objectives is to maintain forest landscape conditions that will support populations of a variety of vertebrate wildlife species, including pine marten. Wishing to propose acceptable alternatives to reserves and set-asides for managing pine marten habitat, SPI contracted with Wildland Resource Managers to conduct research designed to provide insight into how pine marten are currently using managed forestlands. The study, conducted from 1991 through 1993, examined habitat use by pine marten in a managed forest landscape called the Buck Mountain Study Area. This area is located in Northern California and ranges in elevation from about 4,400 feet to over 6500 feet. It is composed primarily of white fir (*Abies concolor*) and California red fir (*A. magnifica*), while lower elevations are dominated by mixed conifer species such as Douglas-dir, (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*) and sugar pine (*P. lambertiana*).

The privately owned Buck Mountain Study Area was first logged in the late 1940s and it is still under private management today. Early management practices predominately emphasized selection harvests coupled with reforestation of brush fields resulting from past wildfires. Current management practices emphasize thinning for release and growth, and regeneration harvests are used to control species composition, reduce fuel loading, and ensure continued sustainable yields. The area currently comprises young-growth true fir and mixed conifer stands, with stand age classes ranging from plantations through about 110 years of age. Scattered widely and sparsely throughout the study area are large-diameter ponderosa pine and incense cedar (*Calocedrus decurrens*) trees and logs left as culls during previous management activities.

Summary of Findings

Study results indicate that the pine marten population in our study area exhibits stable, relatively small home ranges and that the habitat quality, based on our examination of juveniles captured during trapping periods, is relatively high. These findings provide substantial support for the view that habitat for pine marten populations can be managed through the judicious application of scientifically sound forest management techniques without the need for reserves or set-asides. Further, it supports the notion that threats to pine marten and other wildlife habitats from catastrophic wildfire can be reduced on private timberland by an active program of forest management.

Methods

Habitat Classification

Vegetation in the Buck Mountain Study Area was classified using the California Wildlife Habitat Relationships (WHR) system (Mayer and Laudenslayer 1988). The WHR system predicts habitat use by wildlife species based on the vegetative species composition, density class, and size class. The combination of species, density, and size describes a WHR stand condition. Species composition is determined based on the dominant overstory vegetation. Density class is measured by the canopy closure of overstory vegetation. Size class is determined by the quadratic mean diameter of all trees greater than 4.9 inches (in) in diameter at breast height (dbh).

Current vegetation classification was interpreted from 1991 color and 1992 infrared aerial photographs using a minimum polygon size of 5 acres (ac). The photo interpretation data was updated to 1994. Over 85% of the delineated WHR stand polygons (patches) were visually ground-checked for accuracy, with emphasis on those stands that were used by marten. The area was also classified to WHR stages using 1944 black-and-white aerial photographs. Changes in forest landscape conditions over the last 50 years were calculated from the two WHR habitat mapping time periods (1944 and 1994).

Animal Capture and Handling

Pine marten were captured using Hav-A-Hart live traps (12 in x 10 in x 32 in) with attached wooden boxes of a similar size. Canned cat food was used as bait and open traps were checked at least once daily. Traps were closed on most weekends. Field crews moved traps as deemed necessary to facilitate trapping success. Some trap movement was dependent on snow conditions, but most traps were moved based on each field crew's determination of habitat conditions or identified animal tracks.

Captured animals were moved from the live traps into restraining cones made of ¼-inch or ⅛-inch steel rod, similar to those described by Seglund and Golightly (1993). The animals were anesthetized by administering a solution comprising 10 parts ketamine to 1 part valium. Dosage varied by animal weight with the target dosage being 0.05 cc per pound.

Once sedated, each animal was removed from the cone, sexed, weighed, and measured for total length, girth behind shoulders and around the neck, and leg length from hip to toe. A tissue sample was taken from each animal's ear using a 2 mm biopsy punch, and a uniquely colored plastic ear tag (Nasco standard-sized rototag) was inserted in the hole created by the biopsy punch. Tissue samples were sent to the USDA Forest Service Pacific Southwest Forest and Range Experiment Station for storage and eventual genetic analysis. Radio transmitter collars (Telonics) were attached to adult animals for tracking. Radio collars were designed to last approximately 8 months. Upon completion of handling, each animal was placed in a wooden box with a Plexiglas acrylic plastic door to monitor recovery. Upon complete recovery, each animal was released at its capture site. Animals were trapped and collared, re-collared, or had their collars were removed, in the summer or fall of 1991, 1992, and 1993.

Telemetry

Collared animals were located utilizing Telonics receivers (Model TR-2 receiver fitted with a TS-1 scanner) and a Telonics RA-2A directional handheld 2-element "H" antenna. Field researchers utilized four-wheel-drive vehicles, all-terrain vehicles (ATVs), and snowmobiles to access the study area. Fixed stations were marked in the field with numbered wooden stakes, pricked on aerial photographs, and plotted on 1:24,000-scale topographic maps from orthophotographs. These stations were placed at obvious physical locations, such as on prominent points, road intersections, and stream crossings. Other stations were placed between these fixed points using measured distances between known points to achieve a set of known stations approximately 600 to 1300 feet apart. Maps containing these station locations were used to triangulate locations for the animals. For each collared animal, one to three locations were determined per week. Locations were determined using a triangulation of three or more bearings. Attempts were made to gather collared-animal locations during various periods of day and night, but at least 85% of locations were between 6 a.m. and 7 p.m. Efforts were made to approach as close as possible to the animals without disturbing them to minimize the error associated with triangulations. Telemetry data were entered into SPI's geographic information system (GIS). Locations of the fixed stations were first digitized into the GIS from orthophotographs. Field bearings from the fixed stations to animal locations were entered into the system to the nearest degree. For each animal location, the three strongest signals were extended at the given bearing from the mapped station locations. Locations were written into the database. The estimated point location was mapped by intersecting two angle bisectors, and the geographic location (X and Y coordinates, in feet, based on the California Coordinate System [Lambert], Zone I) was added to the database. The animal, date, and time period for each location were added to the database.

We examined two methods to determine the accuracy of our predicted locations: (1) calculated triangulation error polygons from the GIS; and (2) measured error distances. Our accuracy objective was to have the error associated with > 80% of the locations be less than the size of 80% of the habitat patches. Triangulation error polygons were calculated by the GIS from the triangle created by the three directions used to predict the location. Measured error distances were found by obtaining by a predicted location for a non-moving animal (telemetry location) and then walking in to determine the actual location of the animal. The distance between these two locations provided an estimate of the accuracy of the initial telemetry location. This distance was then used as a radius for a circle whose total area was called the measured error polygon. Information developed from measured error polygons and WHR stand sizes were used to maximize the likelihood that actual locations were within the stand types predicted.

Habitat Use

Individual minimum convex polygon (MCP) home range areas were delineated for all marten having at least 10 separate telemetry locations by connecting its outermost locations. The entire area within each individual MCP was considered potentially “available” to the pine marten. Analyses of use versus availability were developed for individual WHR stand types. Analyses were conducted by individual animal to determine the variance of use and by grouping animals together to determine the average use. In order to qualify for use-versus-availability analyses, WHR stand types had to make up at least 5% of the available area or have at least five recorded telemetry visits. To increase the independence of data, all analyses were restricted to using only one location per animal per three days, using the first location received in any one day.

Rest Sites

If, during telemetry monitoring, the transmitter signal strength was non-variable, this was interpreted to indicate that the animal being monitored was not moving. When this condition was found, a walk-in was attempted to determine the specific location of the animal. The transmitter signal strength was monitored during the walk-in attempt to ensure that the animal did not move. If the animal’s stationary location was found and a visual on the animal obtained, the walk-in was considered successful, the site was marked in the field, marked on a field map, and termed a rest site. All rest sites were stratified by the sex of the first animal known to use them, and by season of use (April–September or October–March). From each of these stratified categories, a random sample of 67% of the total available was chosen for sampling in the field. These “chosen” rest sites were revisited and habitat measures were recorded using a +-shaped plot centered on the rest structure and extending 115 feet in the four cardinal directions. Data from the central 1076 square feet of the plot were recorded separately from the rest of each plot’s habitat measures to reduce the bias associated with a non-random plot center, leaving the total area of the plot either 0.1 ac or 0.3 ha, depending on what habitat parameters were measured. Separate habitat measures were recorded specific to each rest structure. Variables measured within the 0.1and 0.3 ac plots included tree canopy closure (average of 48 spherical densiometer measurements), basal area (100% sample of 0.3 ac area), age of rest site stand (average cored age of three to five dominant or co-dominant trees), quadratic mean diameter at breast height of all trees greater than 4.9 in. dbh, and an inventory of dead and down material.

General Habitat Conditions

Dead and down material was sampled throughout the study area using a systematic grid of 0.4 ac plots totaling a 1% sample of the entire study area. Information collected included number of logs, species, diameter, length, decay class, and the arrangement in which they occurred (i.e., single logs or piles, type of piles, and height and length of piles). Forest stand information, including information about snags, was collected using a systematic grid of one variable radius plot per 4 acres, recording diameter, height, species, and decay class (as appropriate) of all trees that fall within the plot. Data for all plots were then aggregated by WHR stand types.

Habitat Capability Model Comparison

Habitats within the study area were assigned habitat suitability index (HSI) values (ranging from 0.0 to 1.0) using the WHR system. This was done by averaging the predicted values for feeding, reproduction, and cover for each WHR stand type in the WHR habitat use matrix for pine marten. A Preference Index (PI) was calculated from our actual use data for each WHR stand type. The PI was calculated as in Thomasma et al. (1991) by dividing the percent use by the percent available. All stand types that were expected to receive 5% of total use or that had a minimum of five recorded animal locations were assigned a WHR habitat value, and a PI was calculated for each of these WHR stand types for full year's use. The PI was compared to the WHR habitat suitability values for similarity using correlation analyses.

Analyses

Statistical analyses regarding habitat selection were conducted according to the methodology presented in Chapter 4 of *Resource Selection by Animals: Statistical Design and Analysis for Field Studies*, by Manly et al. (1993). We used equation 4.27 (log-likelihood chi-squared test statistic) to determine if there was evidence of selection. Equations 4.29, 4.30, and 4.31 were used to estimate the selection ratio and simultaneous Bonferroni confidence intervals for each WHR habitat type. These calculations were conducted on a microcomputer. The relationships between observed habitat use and habitat-use predictions from WHR models were evaluated using simple correlation analyses.

Results

Vegetation Structural Trends Since 1944

The Buck Mountain Study Area does not appear to have been affected by human activities until the early 1920s, when a railroad that came within a few miles of the area was completed. In aerial photographs taken in 1944, several large fire scars are evident, indicated by the relatively large areas of early WHR seral stages. It is not known whether these fires were human-caused, but the logging and increased human activity that the railroad brought likely contributed to the increase of fires in the area after that time. Differences in area composition by WHR stand condition from 1944 to 1994 are shown in Table 1.

Table 1. **Comparison of 1944 and 1994 Buck Mountain Landscapes**

WHR Type*	Percentage of Area in 1944	Average Patch Size (ha)	Percentage of Area in 1994	Average Patch Size (ha)
l,2/S,P	25	100	13	30
2/M,D	6	70	3	70
3/S,P	12	136	7	89
3/M,D	13	80	5	109
4/S,P	1	20	22	55
4/M,D	10	89	38	60
5/S,P	6	94	2	30
5&6/M,D	27	314	10	70
Totals	100	117	100	55

* WHR Type Definitions:
1 = < 1 in dbh
2 = 1-5.9 in dbh
3 = 6-10.9 in dbh
4 = 11-24 in dbh
5 = > 24 in dbh
6 = Size class 5 over a size class 4 or 3, with a D (> 60%) total canopy closure
S = 10–24% canopy closure
P = 25–39% canopy closure
M = 40–59% canopy closure
D = > 60% canopy closure

In general, there has been a reduction in average patch size in almost all size and density classes. This reduction in patch size has been accompanied by large reductions in the acreage of both smallest (WHR 1-3) and largest (WHR 5-6) size classes coupled with a large increase in the WHR 4 size class. The relative acreage of density classes within each size class does not appear to have changed.

These changes in habitat since 1944 can be directly attributed to forest growth and development coupled with forest management activities. These activities have included overstory removal, commercial thinning, selection harvests, and regeneration harvests. All stands within the study area have received one or more harvests over the last 40 years.

In addition to the vegetative changes, the study area has gone from being essentially unroaded to supporting approximately 4.0 miles of open road per square mile.

Habitat Use

A total of 30 adult pine marten were fitted with transmitters during the course of the study. The number of telemetry locations per animal per year ranged from 1 to 85. We recorded at least 10 locations for 22 of the 30 collared marten (15 male, 7 female). For those animals with at least 10 locations, we recorded an average of 42 locations per male (range 10–83) and 35 locations per female (range 14–85). Male MCP home ranges averaged 2540 ac (range 667–6395 ac). Female MCP home ranges averaged 904 ac (range 546–1087 ac).

There are seven WHR forest types within the Buck Mountain Study Area (Table 2). We recorded telemetry locations for pine marten in five of the seven types. Use was not proportional across WHR types, with the true fir types receiving nearly 90% of the use. The white fir type was used significantly more than expected and the other types were used as expected, less than expected, or they composed too little of the area to test ($X^2 = 112.5$, $P < .05$).

Table 2. **The Availability and Use by Pine Marten of WHR Forest Types Within the Buck Mountain Study Area**

WHR Forest Type	% Available	% Use	Selection*
White Fir (WFR)	59.2	77.9	+
Red Fir (RFR)	19.5	10.9	–
Mixed Conifer (SMC)	14.9	9.7	–
Montane Chaparral (MCH)	2.4	0.3	–
Ponderosa Pine (PPN)	2.2	1.2	0
Lodgepole Pine (LPN)	1.1	0.0	N
Closed-Cone Pine (CCP)	0.7	0.0	N

*Selection tests were done at the P < .05 level.
+ = Used significantly more than expected
0 = Used as expected
– = Used significantly less than expected
N = Not testable

There were a total of 37 WHR species, size, and density class combinations (WHR stand types) available within the study area. One or more marten telemetry locations were recorded in 32 of the 37 stand types available. Twenty WHR stand types met our criteria for use testing (Table 3). Considering both sexes and all seasons, pine marten selectively used WHR species, size, and density combinations ($X^2 = 296.3$, $P < .05$). Use of WFR4D and WFR4M was significantly greater than expected, while use of SMC1, RFR6, RFR4D, RFR4M, RFR4P, and RFR4S were used significantly less than expected. The other 12 WHR stand types meeting the use testing criteria were used as available.

Table 3. **Availability and Use of WHR Stand Types by Pine Marten Considering Both Males and Females Across All Seasons**

WHR Stand Type	% Available	% Use*	Selection**
WFR4D	13.6	29.4	+
WFR4M	13.5	20.1	+
WFR4S	10.9	10.0	0
WFR6	5.0	4.6	0
SMC3P	4.3	6.1	0
WFR4P	4.2	3.5	0
RFR4D	4.0	1.7	–
SMC4P	3.7	5.1	0
RFR4P	3.7	1.5	–
RFR4S	3.5	0.7	–
SMC1	2.8	1.2	–
WFR5M	2.7	4.0	0
RFR4M	2.7	0.7	–
RFR6	2.5	1.2	–
PPN1	2.3	1.4	0
WFR1	1.7	0.8	0
WFR3S	1.6	1.0	0
WFR5P	1.2	1.4	0
RFR5P	0.8	0.7	0
WFR3M	0.4	0.8	0
OTHER	14.9	4.1	–

* A minimum of five locations were used per WHR stand type (0.7% of the 869 total telemetry locations).

**Selection tests done at the P < .05 level:

+ = Used significantly more than expected

0 = Used as expected

– = Used significantly less than expected

Pine marten used habitats differently in the spring/summer period (April–September) than in the fall/winter period (October–March), and this change in use varied by sex. Male marten tended to use denser stands more in summer than winter and more open stands less in summer than in winter ($X^2 = 24.8$, $P < .05$). Males used the WFR4D stand type significantly more in summer than in winter and the SMC4P stand type significantly less in summer than in winter, while using the other WHR stand types tested similarly in summer and winter. Female marten continued to use dense stands in the winter as they did in the summer but tended to make more use of open stands in summer than in winter ($X^2 = 104.7$, $P <0 .05$). Females used the SMC3P stand type significantly more in the summer than in winter, the WFR4M stand type less in summer than in winter, and the other stand types tested similarly in both seasons. Combining sexes, marten tended to use denser stands more in the summer and open stands more in the winter ($X^2 = 74.4$, $P < .05$).

Considering both seasons, female marten used habitats somewhat differently than males, with a tendency to use dense stands more than males and to use open stands less than males ($X^2 = 64.4$, $P < .05$). Compared to male marten use, females used the WFR4D stand type significantly more than expected and used the SMC3P and SMC1 stand types significantly less than expected. Female marten used the other WHR stand types as they were used by males.

Rest Sites

One hundred fifty-seven rest sites were recorded by "walking in" on collared pine marten. Rest sites were recorded in 22 of the 37 available WHR stand types. In general, marten used the WHR stand types for rest sites in the same proportion as marten used the stand types as predicted by telemetry locations (Table 4).

Table 4. **Availability and Use of WHR Stand Types by Pine Marten by Telemetry Locations and Rest Site Locations for All Marten and All Seasons**

WHR Stand Type	% Available	% of Telemetry Locations (n=869)	% of Rest Site Locations (n=157)
WFR4D	13.6	29.4	21.5
WFR4M	13.5	20.1	33.6
WFR4S	10.9	10.0	4.7
WFR6	5.0	4.6	12.1
SMC3P	4.3	6.1	1.9
WFR4P	4.2	3.5	3.7
RFR4D	4.0	1.7	2.8
SMC4P	3.7	5.1	2.8
RFR4P	3.7	1.5	1.9
RFR4S	3.5	0.7	0.0
MCH	2.9	0.3	0.0
SMC1	2.8	1.2	0.9
WFR5M	2.7	4.0	0.9
RFR4M	2.7	0.7	0.9
RFR6	2.5	1.2	0.0
RFR5S	2.4	0.3	0.0
PPN1	2.3	1.4	0.0
OTHER	15.3	8.2	12.3

Forest stands with canopy closures between 40 and 59% composed 20.9% of the study area and contained 40.2 percent of the rest sites. Canopy closures greater than 39% composed 46.0% of the study area and contained 76.6% of the rest sites. Forest stands with quadratic mean diameters of between 28.1 and 61 cm composed 63% of the area and contained 74.8% of the rest sites.

Twenty-three percent of the rest sites occurred in stands that averaged less than 40% total canopy closure, but only 9% of the rest sites (within 115 feet) had canopy closures less than 40%. While 64% of the rest sites occurred in stands that averaged less than 60% total canopy closure, only 32% of the rest sites (within 115) had canopy closures less than 60%.

Vegetative and structural variables associated with pine marten rest sites were generally highly variable (Table 5). Consistently high canopy closure at summer rest sites and a relatively large number of logs at all rest sites were the most consistent features measured. Other than stand density, there were no significant differences between summer and winter rest sites for any of the variables measured within 115 feet of the rest structure. We compared the average values of variables associated with rest sites with the average values of the same variables from random sites in WHR stand types that were used differentially by marten (Table 6). Except for "snags/ac" and "logs/ac," there were no consistent differences for any of the other variables measured. On average, the number of logs/ac and number of snags/ac tended to be much greater at rest sites than in stands in general, regardless of whether marten use varied by WHR stand type. The 157 marten rest sites occurred in four major structure categories: (1) logs and log piles; (2) green tree limbs and cavities; (3) snags; and (4) stumps, rock piles, other in-ground sites. Fifty-nine percent of the log rest sites were composed of isolated single logs, and 61% of the snag rest sites were isolated single snags. Over 40% of the log rest sites were logs felled and left because of cull nature or were slash piles and windrows from past logging and road-building activities. Male and female marten changed the proportional use of these four structure categories by season (Table 7). Males generally used a wider variety of rest sites in the summer and females used a wider variety in the winter. In winter, 63% of male rest sites were in logs, while in summer males used logs 37% of the time. Female marten used snags 60% of the time in winter and 29% of the time in summer. Female marten used snags as rest sites more often than males and were more consistent in their use of log rest sites.

Table 5. **Vegetative and Structural Variables Within 115 Feet of Pine Marten Rest Sites**

	Age (Yrs)	QMD (in)	Basal Area (ft^2/ac)	Trees > 2.4 in dbh (#/ac)	Structure Diameter (in)*
Mean	70	15.3	194.5	150	34.0
S.D.	13	72.9	94.6	64	13.0
Min.	29	9.1	18.7	29	8.0
Max.	102	27.7	584.7	395	77.9
Median	68	15.2	184.4	146	32.8
	% Summer Canopy Closure	**% Winter Canopy Closure**	**Dist. to Disturbance** (ft)**	**Dist. to Water (ft)**	
Mean	72	60	125	1,417	
S.D.	14	18	23	1,227	
Min.	43	0	75	0	
Max.	95	95	230	6,339	
Median	77	65	125	1,001	
	Logs > 11 in Diameter (#/ac)	**Snags > 10.9 in dbh (#/ac)**	**Snags > 24 in dbh (#/ac)**		
Mean	65.9	7.4	1.0		
S.D.	34.9	9.4	1.8		
Min.	13.5	0.0	0.0		
Max.	175.4	33.7	6.7		

*Structure diameter is the dbh of the tree or snag, or the large-end diameter of the log used by a marten as a rest site.
**Disturbance is defined as a site specific man-caused change to the environment, such as a stump, road, skid-trail, regeneration harvest unit, etc.

Table 6**. Comparison Between Stand Variables Measured at Marten Rest Sites and Stand Variables Measured at Random Within Selected WHR Stand Types.**

WHR Stand Type**	*Basal Area (ft^2/ac)*	*Trees>2.4 in (# /ac)*	*QMD (in) (dbh)*	*Trees > 24 in (# /ac)*	*Trees > 34 in (# /ac)*	*Logs > 11 in (# /ac)*	*Snags > 24 in (# /ac)*
Rest Site Average*							
	194.5	*150*	*15.3*	*15.8*	*2.4*	*65.9*	*1.0*
(+) WFR4D	210.6	152	16.0	17.8	0.8	52.5	0.3
(+) WFR4M	178.8	154	14.9	12.9	0.8	44.2	0.3
(0) WFR6	201.4	154	14.8	10.9	0.8	43.8	1.0
(0) WFR4P	134.7	131	14.2	8.1	0.8	33.3	0.2
(0) WFR5M	254.2	145	18.5	31.2	6.9	59.3	0.3
(-) RFR4D	259.4	213	14.7	15.8	0.8	53.0	0.3
(-) RFR6	267.3	171	17.0	25.1	6.1	53.8	0.4
(-) RFR4P	139.5	142	17.6	6.1	0.8	53.4	0.4
(-) RFR4M	212.3	210	13.8	12.1	2.0	44.7	0.1

* Data from marten rest sites.

** A + indicates stand types selected for, a 0 indicates stand types used as available, and a – indicates stand types used less than as available.

Table 7. **Percent Use of Structural Categories of Marten Rest Sites by Sex and Season of Use**

Rest Site Category	Male		Female	
	Summer	Winter	Summer	Winter
Logs	37	63	40	41
Green Trees	16	9	0	12
Snags	26	12	60	29
Stumps	21	16	0	18

We did not find a significant correlation between the WHR system predictions of marten use of WHR stand types and our telemetry results ($r^2 = .036$, $p = .437$). The major discrepancies between predicted and actual use were associated with the red fir stand types, which were used much less than predicted, and the use of relatively open white fir and mixed conifer stand types, which were used much more than predicted.

Discussion

While we have no direct measure of pine marten use of our study area in 1944, our data indicate there has been a 380% increase since that time in the amount of acreage of WHR 4M and 4D stand types, which we found to be heavily used by pine marten. We also found a 48% decrease in the WHR 1,2/S,P stand types, which are little used by pine marten. We also detected a substantial decrease in the average patch size within the study area since 1944. We do not know if marten are affected by changes in patch size at the scale we calculated. However, the home range sizes we measured were not different from those found in other studies, suggesting that decreases in patch size have not caused an increase in home range size, as might be expected if smaller patch size decreases habitat capability (Raine 1983).

Overall, our data suggest that, since 1944, there has been an increase in the habitat capability of the area to support pine marten—an increase that has occurred in concert with relatively intense forest management activities over the last 40–50 years. We recorded over 60% of pine marten use in three WHR stand types. Overall, a wide variety of WHR stand types were used, both by locations predicted by telemetry data and by rest site locations. This use of a wide variety of WHR stand types by pine marten suggests that the scale and parameters used to define stand types (species, size class, density class) do not directly include some parameters of importance to pine marten. For instance, while we found that pine marten rest sites were consistently associated with relatively high canopy closure, we also recorded a substantial number of rest sites in relatively open forest stands. This suggests that marten were willing to use small areas of dense canopy within stands that were more open on average. Our typing was limited to stands at least 2 ha in size, causing us to "overlook" these small areas. This indicates that marten in our study area are using relatively open forest stands where the canopy closure is clumpy in nature rather than homogenous over the entire stand.

In addition, marten in our study area used rest sites that differed from average stand conditions in the amount of dead and down material and the number of relatively large snags present. Our data for these habitat parameters suggest that this is another example where marten were choosing from a clumpy distribution of snags and logs rather than from a homogenous distribution. Because of the high variability associated with densities of snags and logs across our study area, we were unable to statistically discriminate different levels of these habitat variables between rest sites and random sites. However, we believe that they are an important habitat component for pine marten.

The set of habitat variables we collected at marten rest sites and at random sites within WHR stand types was not adequate to predict the patterns of use we observed, both as predicted by telemetry locations and as recorded from rest sites. In particular, we cannot explain the lack of use of the red fir stand types in our study area. We believe this suggests that other habitat parameters than those normally measured are in large part accounting for the use patterns we observed.

Other researchers have suggested that marten choose rest sites, and use habitat in general, because of thermal properties or the availability of prey. In our study area, winter rest sites did not vary from random sites in terms of winter temperatures[1] (unpublished data from our study area). This suggests that, in our study area, prey availability is the most likely determinant of habitat use by pine marten, at least in winter. Data from our study area strongly suggest that marten are selecting for stand types and within stand patches that provide access to an adequate prey base.

Management Implications

Substantial research over long time periods will be necessary in order to determine the range of landscape and stand structures that will assure viable pine marten populations. We are not aware of any ongoing studies that will lead to this level of understanding of pine marten ecology and

[1] Temperature data were collected during the winter season, comparing rest sites with random sites using continuous temperature measuring devices. No differences in winter temperatures were observed between rest sites and random sites.

habitat management, nor do we believe that economically viable techniques to accomplish this are available at this time. Thus, we offer another approach—that of describing landscapes which currently support stable, reproducing populations of pine marten—as a surrogate for a complete understanding of pine marten ecology. Our data suggest that management for pine marten habitat, in areas similar to our study area, will likely require landscapes composed of between 30 and 40% WHR4M or WHR4D stand types and that contain no more than 20–25% of the area in the WHR "S" density category. The units of implementation of these landscape percentages should be at least the size of marten home ranges and should be adjacent to each other across much larger scales to allow interaction between large numbers of individuals.

In addition, managing for a "clumpy" stand structure in terms of canopy closure, snags, and dead and down material is likely to enhance use by pine marten. The scale of "clumps" in our study area appears to range from an individual feature (snag, log, rock pile) to an area between 0.1 and 5 ac, but likely it also varies depending on the overall stand conditions within which the clumps occur. For instance, large, very open stands may require larger, more closely spaced clumps. While our data are inadequate to definitively determine the desired number of clumps, within our study area dead and down clumps similar to those used by marten occur at a density of approximately 1 per 24-50 ac.

Research Needs

A better understanding is needed regarding the relationships among pine marten use of forest stands, prey availability, and predator avoidance. A clearer understanding is needed regarding our ability to provide within-stand structures that enhance prey availability and to provide adequate hiding cover. This is particularly true in recently regenerated stands and in rehabilitation efforts following catastrophic wildfire. As we learn more about these relationships, our ability to manage for sustainable marten populations should be substantially enhanced.

Literature Cited

Buskirk, S., and R. Powell. 1994. Habitat Ecology of Fishers and American Martens. In: S. Buskirk, A. Harestad, M. Raphael, and R. Powell, eds. *Martens, Sables and Fishers.* Ithaca, NY: Cornell Univ. Press.

Grinnell, J., J. Dixon, and L. Linsdale. 1937. *Furbearing Mammals of California: Their Natural History, Systematic Status and Relations to Man.* Vol. 1. Berkeley: Univ. of Calif. Press.

Manly, B., L. McDonald, and D. Thomas. 1993. *Resource Selection by Animals: Statistical Design and Analysis for Field Studies*. London, Engl.: Chapman and Hall.

Mayer, K., and W. Laudenslayer. 1988. *California Wildlife Habitat Relationships System.* Sacramento, Calif: Calif. Dept. Fish and Game.

Raine, R. 1983. Winter Habitat Use and Responses to Snow Cover of Fishers (*Martes pennanti*) and Martens (*Martes americana*) in Southeastern Manitoba. As cited in S. Buskirk, A. Harestad, M. Raphael, and R. Powell, eds. *Martens, Sables and Fishers.* 1994. Ithaca, NY: Cornell Univ. Press.

Seglund, A., and R. Golightly. 1993. *Fisher Survey Techniques on the Shasta-Trinity National Forest.* Progress Rept. May 1, 1992, through December 1, 1992. Coop. Agreement No. PSW-92-0026CA. Arcata, Calif: Humboldt State Univ.

Thomasma, L., T. Drummer, and R. Peterson. 1991. Testing the Habitat Suitability Model for the Fisher. *Wildl. Soc. Bull.* 19:291–297.

US Department of Agriculture (USDA). 1993. *Forest Ecosystem Management: An Ecological, Economic, and Social Assessment (FEMAT).* Multi-Federal Agency Rept. to the President. Washington, D.C.: USDA.

Verner, J., K. McKelvey, B. Noon, R. Gutierrez, G. Gould, and T. Beck, eds. 1992. *The California Spotted Owl: A Technical Assessment of Its Current Status.* PSW Gen. Tech. Rept. PSW-GTR-133. Albany, Calif: USDA Forest Service.

Available Contacts and Resources

Relevant Databases, Documents and other Resources	Where to Find Them
✓ California Wildlife Habitat Relationships (WHR) System	Contact the California Dept. of Fish and Game, Sacramento, Calif.