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Habitat Selection of American Martens on Northeast Chichagof Island, Southeast Alaska, 1991–1997

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Alaska Department of Fish and Game Division of Wildlife Conservation

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Abstract

We determined macro-scale habitat selection by American martens in a portion of coastal Southeast Alaska during 1991–1992 through 1997–1998. We located 137 radiocollared martens (86 males and 51 females) 2,978 times to determine habitat selection at the stand and landscape levels on northeast Chichagof Island. Martens showed the greatest selection among forested old-growth forest habitats during the winter followed by summer. During the fall, little selection was observed among forested habitats. Selection ratios for nonforest habitats were always small, confirming a general avoidance of nonforest by martens. Martens showed the greatest selection for Large/MS old-growth forest (selection ratio = 1.39) and Medium/MS old-growth forest habitats (selection ratio = 1.30). The mean selection ratios of these 2 habitats were not significantly different from each other, but both were significantly greater than any other habitat. Intermediate/MS old-growth forest stands (1.11) were selected less than the larger-sized habitats, but more than Small/MS old-growth forest (0.72), Singlestoried (0.81), and nonforested sites (Shrub = 0.20 and Sparsely Vegetated = 0.30). Larger-sized multistoried old-growth forest contained greater number of large woody structures, including live trees, snags, and logs. These habitats also had greater overstory canopy cover. For most habitat categories, the 95% confidence intervals (CIs) for the observed marten selection indices overlapped with the values in the interagency habitat capability model indicating model parameters were reasonable. The wet, cool climate of the North Pacific Coast presents martens with unique challenges including obtaining adequate food, maintaining thermal balance, and finding protection from avian predators. Habitats with greater structure best meet these ecological requirements. Clearcut logging, the predominant method of tree harvesting in western North America, removes vertical structures and overhead cover important to martens, such as live trees and snags. Selective logging approaches that would retain significant vertical woody structure in a unit should be explored to maintain habitat value.

Key words: Chichagof Island, forest structure, habitat selection, *Martes americana*, Southeast Alaska.

Introduction

Researchers have found American martens (*Martes americana*) associated with late-succession and old-growth forests across North America, especially stands with abundant woody structure (Strickland and Douglas 1987, Buskirk 1992, Buskirk and Ruggiero 1994). Martens are among the most habitat-specific mammals in North America (Clarke et al. 1987, Buskirk and Ruggiero 1994). Many marten populations have declined with the removal of forested habitat along with increased human access, and unrestricted trapping (Clark et al. 1987, Bissonette et al. 1989, Thompson and Harestad 1994). Also, martens have been impacted by greater fragmentation of their habitat by cutting and road building (Bissonette et al. 1989, Bissonette et al. 1997, Cushman et al. 2011). In western North America, martens are closely tied to mesic, late-successional or old-growth, coniferous forests (Koehler et al. 1975, Koehler et al. 1990, Jones and Raphael 1992, Buskirk and Ruggiero 1994, Raphael and Jones 1997, Bull et al. 2005, Slauson et al. 2007, Shirk et al. 2014), especially in Southeast Alaska (Koch 2016). Mesic old-growth forests are structurally diverse with a variety of tree sizes, dense multilayered canopies, and an abundance of coarse woody debris (CWD) (i.e., snags, stumps, and downed logs) (Franklin et al. 1981, Alaback and Juday 1989, Samson et al. 1989). Although the temperate rainforests in Southeast Alaska are always cool and wet, stand structural characteristics differ greatly among old-growth forest types because of site and soil conditions (Alaback and Juday 1989, Martin 1989, Caouette and DeGayner 2008). Also, industrial-scale logging has converted large areas of old-growth forest habitat into clearcuts and regenerating second growth (USFS 1997, 2008). Given the entire North Pacific Coastal region is dominated by conifer forests and mesic conditions (Alaback and Juday 1989), our study explored whether martens selected habitats based on stand structural characteristics. We hypothesized that martens would select forested habitats within the available landscape and the selected stands would have greater woody structure, including large live trees, snags, and logs.

Clearcut logging, the predominant method of tree harvesting in western North America, has negatively affected marten populations in many regions (Marshall 1951, Campbell 1979, Soutiere 1979, Snyder and Bissonette 1987, Buskirk and Ruggiero 1994, Katnik et al. 1994, Thompson and Harestad 1994, Hargis et al. 1999, Potvin et al. 2000, Payer and Harrison 2003). In typical clearcuts, all standing structures, such as live trees and snags, are felled (Franklin and Forman 1987). Usually, martens avoid areas with little overhead cover (Simon 1980, Spencer et al. 1983, Buskirk and Ruggiero 1994). Numerous studies have shown the importance of vertical structure for dens and resting sites (Buskirk et al. 1989, Raphael and Jones 1997, Ruggiero et al. 1998, Schumacher 1999, Bull and Heater 2000). Furthermore, overstory canopy cover provides protection from the elements and avian predators (Clark et al. 1987). Large CWD provides resting sites for martens (Martin and Barrett 1991, Schumacher 1999) and habitat for potential small mammal prey (Ben-David et al. 1997, Flynn et al. 2004), especially voles (Koehler et al. 1990, Bull and Blumton 1999, Flynn and Schumacher 2009). Although an abundance of CWD may exist immediately after clearcutting, the amount and size of CWD will decline as the slash and residual CWD decay (Franklin and Waring 1980). Because most of trees have been removed following clearcutting, large CWD will not be recruited into the stand for 150 years (Alaback 1984). With a 100-year timber rotation, the trees will not grow to an adequate size within the 100-year time frame. Thus, abundant CWD in recent clearcuts probably is of little value to them. However, martens will use residual CWD in second-growth stands (Baker 1992), but how long these structures will remain useful to martens is poorly known. Highly decayed CWD probably provides less value to martens (Wilbert 1992, Schumacher 1999). New logs or snags of sufficient size to accommodate marten dens or resting sites may require over 150–200 years to develop (Franklin et al. 1981). Currently planned 100-year timber rotation times on managed forests will not permit the formation of large vertical structures or CWD before the next cutting (USFS 1997, 2008).

Martens were selected as a management indicator species for the Tongass Land Management Plan (TLMP) because of concerns for habitat degradation by clearcut logging (Sidle and Suring 1986, USFS 1997, 2008). About 325,772 ha (805,000 acres) of old-growth habitat have already been logged on the Tongass National Forest (TNF), nearly all by clearcutting (USFS 2008). The revised TLMP has scheduled an additional 187,370 ha (463,000 acres) of old-growth forests for timber harvest beginning in 2008 (USFS 2008).

For the TLMP, an interagency group of biologists developed a habitat capability model for martens in Southeast Alaska (Suring et al. 1993). Land managers envisioned that the habitat capability model would be used to evaluate the effects of management alternatives on marten habitat. The initial model assigned relative values to landcover types based on best professional judgement (Suring et al. 1993). On the TNF, the available mapped landcover types were derived from a timber-based classification (Caouette et al. 2000). Timber-type classes were assumed to indicate degree of canopy closure, availability of snags, and presence of down and dead wood (Suring et al. 1993). The habitat capability model was revised slightly in 1995 (Flynn 1995) based on habitat selection data collected during the early phases of this study (Flynn 1991). Subsequent to initial model development, the utility of the habitat capability model approach was questioned, primarily because habitat selection may not establish a cause-and-effect relationship with carrying capacity (DeGayner 1993). In order to further evaluate the marten habitat capability model, we wanted to compare model coefficients with habitat selection ratios for the entire data set. Because of changing habitat maps, we needed to develop a crosswalk between the timber-based landcover map (Caouette and DeGayner 2008) and the map derived from LANDSAT TM imagery (Pacific Meridian Resources 1995, Fehringer 1997).

Study Area

In Southeast Alaska, the TNF encompasses 80% of the land area. We chose northeast Chichagof Island, located in the northern portion of Southeast Alaska (57–58°N, 135–136°E) about 80–160 km west of Juneau, Alaska for the study because its topography and habitats were typical of northern Southeast Alaska (Fig. 1). In addition, logging roads provided good access, part of the area had been logged, camp facilities were available, and the area was relatively close to Juneau.

The primary study area comprised lands adjacent to Salt Lake Bay (125 km^2) that was bounded by Port Frederick to the north, Tenakee Inlet to the south, the portage (a narrow strip of land between the large water bodies) on the west, and the Game Creek and Indian River drainages on the east and north (Fig. 2). In 1992, we extended the study into the upper Game Creek watershed (102 km^2), located north of Salt Lake Bay. Most of the study area was under the jurisdiction of the U. S. Forest Service (USFS) within the Chatham Area, TNF. The archipelago has a maritime climate; summers are cool and wet and winters are characterized by deep snow (2,360 mm annual precipitation). The snow-free period extends from early May to early November at lower elevations (<1000 m). Vegetation at higher elevations is typically alpine tundra, and in lower elevations coastal, old-growth forest of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) with well-developed understory (mainly *Oplopanax horridum*, *Vaccinium* sp., *Menziesia ferruginea*, and *Rubus* sp.).

Between 1949 and 1952, U. S. Fish and Wildlife Service personnel released 21 martens (5 males, 8 females, 8 unknown) near the community of Pelican on Chichagof Island to establish populations for human use (Elkins and Nelson 1954). Stone et al. (2002) found these animals genetically similar with their source populations on the mainland coast. Our study area encompasses 6 streams that support an annual run of spawning Pacific salmon (*Oncorhynchus gorbuscha, O. keta*, and *O. kisutch*), from late summer to late autumn. The nonvolant mammalian fauna of the island includes: Keen's deer mice (*Peromyscus keeni*), long-tailed voles (*Microtus longicaudus*), tundra voles (*Microtus oeconomus*), red squirrels (*Tamiasciurus hudsonicus*), common shrews (*Sorex cinereus*), Sitka black-tailed deer (*Odocoileus hemionus sitkensis*), American mink (*Neovison vison*), North American river otters (*Lontra canadensis*), and brown bears (*Ursus arctos*) (MacDonald and Cook 2007). The resident avian fauna includes Steller's jay (*Cyanocitta stelleri*), sooty grouse (*Dendragapus fuliginosus*), and winter wren (*Troglodytes troglodytes*). Other song birds such as dark-eyed junco (*Junco hyemalis*), robin (*Turdus migratorius*), varied thrush (*Ixoreus naevius*), hermit thrush (*Catharus guttatus*), and Swainson's thrush (*Catharus ustulatus*), arrive on the island for the breeding season in early May and depart during September.

About 7% of the Salt Lake Bay study area was logged from 1984 to 1988 and 27 km of logging roads were constructed. An additional 486 ha were clearcut from 1990 to 1992 (USFS 1989). Logging activity began in June 1990 with the construction of about 10 km of logging road in the western portion of the study area. Two units were felled before a court injunction suspended all logging activity at the end of June 1990. The court lifted the injunction during August 1991, and logging resumed September 1991. Logging activity continued until 10 December 1991 and nearly one half of the units were felled. Logging activity was suspended for the winter and

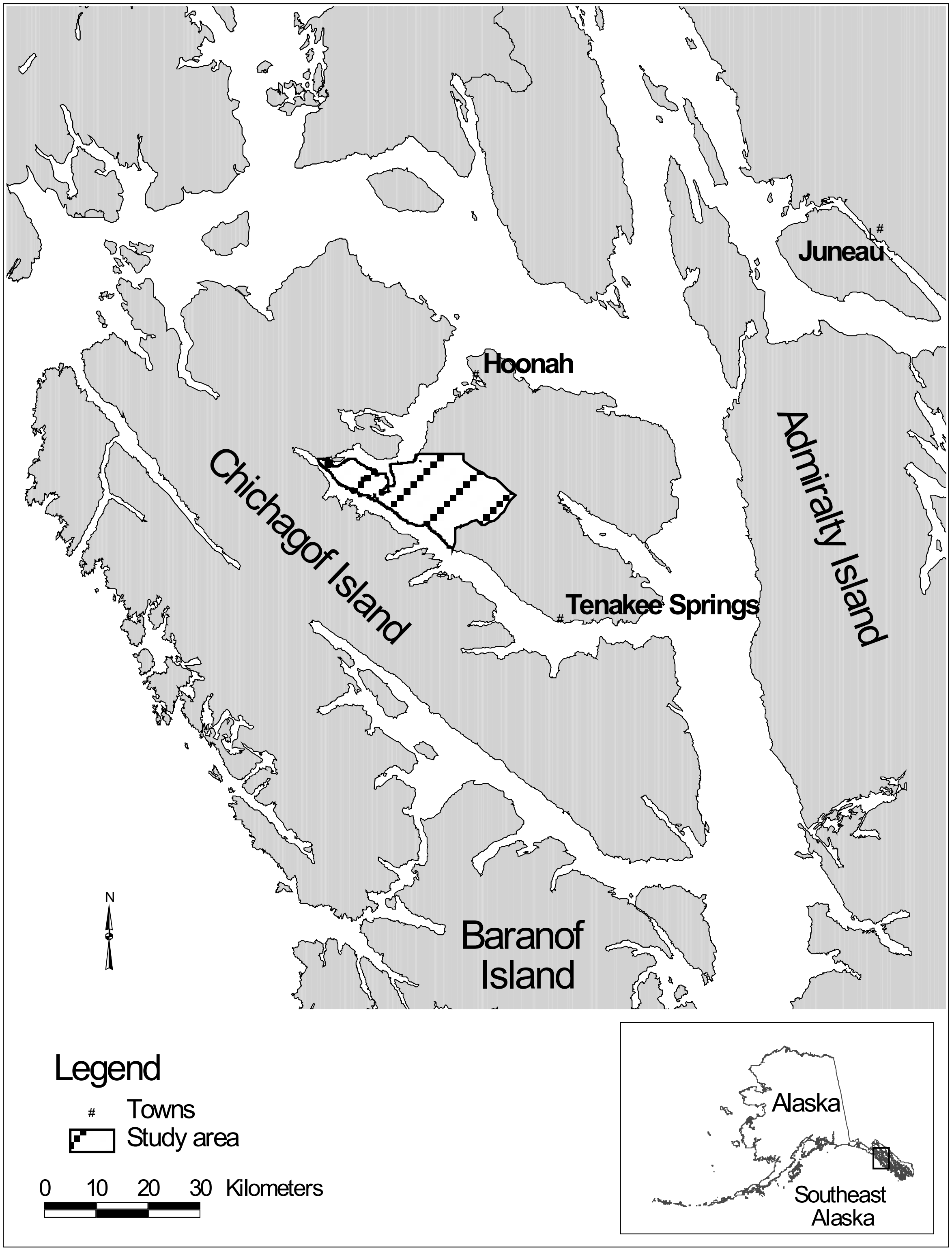

Figure 1. Location of study area on northeast Chichagof Island, Southeast Alaska.

Figure 2. A photograph of the study area in late winter.

resumed in April 1992. All logging activity in the Salt Lake Bay area was completed by 31 October 1992.

Methods

Habitat Use

We used a Design II sampling protocol for this study (Manly et al. 2002). Resource use of individual martens was recorded, and then compared with resource availability for the population level (i.e., the entire study area). We captured and radiocollared a sample of martens on the primary study area. Martens were live-trapped throughout the year at permanent trap sites systematically located along the logging road system. Trap sites were usually about 500 m apart. Traps (Models 203 and 205, Tomahawk Live Trap Co., Tomahawk, WI) were baited with either strawberry jam, sardines, or venison scraps, covered with a green tarp, and placed under a log or the base of a tree at trap sites. We checked the traps daily. Captured martens were pressed in the end of the trap using a folded blanket and injected with a mixture of 18.0 mg/kg ketamine hydrochloride (Vetalar®) and 1.6 mg/kg xylazine hydrochloride (Rompun®) for immobilization. For short-term chemical restraint, we used a dosage of 13.0 mg/kg of ketamine and 1.0 mg/kg xylazine. All captured martens were eartagged (Size 1, Style 1005, National Band and Tag Co., Newport, KY), sexed, weighed, and measured. Two first premolar teeth were pulled for age determination by cementum analysis (Matson's Laboratory, Milltown, MT). We drew a 3.0 cc blood sample from the jugular vein from most captured animals, separated the serum, and then froze both portions for future analyses for disease, diet, and pregnancy studies. We radiocollared most of the captured martens, primarily adults previously captured on the study area. On female martens, we used 2 radio collar types; each weighed about 35 g with an expected life of 12 months (Telonics MOD-073, Telonics, Mesa, Arizona USA and Lotek SMRC-4, Lotek Engineering, Newmarket, Ontario CAN). On males, we used a 49-g collar (Telonics MOD-080, expected life of 12–18 months). After a marten had recovered from the immobilization, we released it near the capture site. Martens recaptured during the same trapping session were released without additional processing. During subsequent trapping sessions, all recaptures were chemically restrained, weighed, and measured. We replaced collars on several animals throughout the year. All capture and handling procedures were consistent with the animal care guidelines of the American Society of Mammalogists (Sikes and Gannon 2011). We did this research before the State of Alaska implemented capture and handling protocols.

We considered radiocollared martens that showed fidelity to a home range area a resident animal. Martens that moved over an area >2 home ranges within a season and covered areas occupied by other resident martens, were labeled transients. We classified martens more than 1 year old as adults. Young-of-the-year animals, or birth-year martens, were called juveniles.

We located radiocollared martens from small aircraft (Mech 1974, Kenward 1987) during daylight hours throughout the year. After we located an animal by circling in the aircraft, we plotted the marten's location on paper copies of high-resolution orthophoto maps (1:31,680 scale). At the office, we transferred the locations to mylar overlays on color aerial photographs (1:15,840 scale) for a permanent record. The locations were digitized on onscreen using digital versions of the orthophoto maps and geographic information system (GIS) software (ArcView 3.1, ESRI, Redlands, CA) on a personal computer. Additional attribute information for each location was obtained from the GIS using coverages of elevation, slope, and aspect for each location by sampling grids based on a digital elevation model of the study area. Because only 5% of the marten locations were at elevations greater than 500 m, we truncated our locations to only ones less than <500 m.

We found that our location accuracy averaged about 105 m (n = 15, SE = 33) based on blind comparisons of known locations. Thus, each point location was buffered by 105 m to create a 3.12-ha circular polygon centered on the marten location. We intersected the marten location polygons with the landcover map to determine the composition of habitats around each telemetry location. We determined proportionate habitat use of individual martens by summing the area of each habitat type within their relocation polygons and dividing by their total area. We used location polygons instead of the points to incorporate telemetry and mapping error into the analyses. Also, polygons better described habitat associations around the location.

HABITAT AVAILABILITY

We chose the size/structure map developed from LANDSAT TM imagery (Pacific Meridian Resources 1995, Fehringer 1997) to define marten habitats. Because of problems with the spatial accuracy of the USFS's timber-type map (Brickell 1989), we felt that the size/structure map provided the best spatial representation of the structural features of the forest. Also, we preferred the LANDSAT TM data because the size/structure map had a small (900 $m^{2)}$ minimum mapping unit (because of the 30-m pixel size) and good spatial accuracy. The size/structure map was developed to distinguish forest stands by their density of trees by size class and to separate stands with multistoried canopies (old-growth forests) from singlestoried (second-growth forests). We received a polygon coverage from the USFS that was created from the raster landcover map by grouping similarly-coded, adjacent pixels into polygons (Gary Fischer, USFS, Juneau, personnel communication). To choose the area that was available to martens, we selected all the locations of resident martens over the years of the study and then we drew a 105-m buffer around the outermost locations. To be consistent with the marten locations, we truncated our habitat available area to polygons <500 m in elevation.

For this project, we collapsed the 17 size/structure categories into 8 strata (5 forest strata and 3 primarily nonforest strata) (Table 1). The multistoried, old-growth forest categories were large/multistoried (Large/MS), medium/multistoried (Medium/MS), intermediate/multistoried (Intermediate/MS), and a combined Small/multistoried and pole/multistoried class (Small/MS). We collapsed all of the singlestoried classes, usually second-growth forest, into a single category called Singlestoried because the singlestoried classes represented only a small proportion (2.9%) of the study area. The 3 nonforest strata were grouped into Shrub, Sparsely Vegetated (combined herbaceous, rock, and snow), and Clearcuts (<25 years old). Recent clearcuts represented a specific habitat condition with known boundaries that were mapped from other USFS GIS data. Because the landcover map was interpreted from 1992 satellite imagery, some of the clearcuts were more recent, so we adjusted the map accordingly to make the Clearcut stratum. Previously, the Clearcut stratum was mapped as follows: Sparsely Vegetated (6.4%), Shrub (34.0%), Large/MS (12.9%), Medium/MS (21.2%), Intermediate/MS (7.4%), Small/ MS (3.8%), and Singlestoried (9.1%).

HABITAT ATTRIBUTES

For the study, we field sampled 65 stratified, random locations and 67 sites centered on marten dens or resting sites to evaluate map accuracy and habitat structure by type. We selected a random sample of 8 polygons within each stratum for field sampling (total of 64 polygons). Only

Table 1. Number of trees/snags by size class by LANDSAT TM mapped size strata for all sites, northeast Chichagof Island, Southeast Alaska. Plots represent the aggregation of 4 0.017-ha subplots per site or 0.07 ha in total area.

Landcover strata	No. plots	No. large[a] trees		No. medium[b] trees		No. intermediate[c] trees		No. small[d] trees		No. pole[e] trees	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Shrub	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Singlestoried	8	0.4	0.3	1.9	0.7	9.0	2.0	22.2	2.9	32.1	8.0
Large/MS	17	2.8	0.4	2.8	0.5	3.9	0.6	6.2	1.1	7.8	1.6
Medium/MS	28	2.3	0.3	3.0	0.3	5.8	0.7	8.3	0.8	13.6	1.8
Intermediate/MS	30	1.3	0.3	2.6	0.4	6.0	0.6	10.4	1.0	14.9	1.7
Small-pole/MS	17	0.5	0.2	1.5	0.4	4.3	0.8	12.6	1.7	17.2	1.7
Clearcut	15	0.0	0.0	0.5	0.3	0.6	0.4	0.8	0.6	1.5	0.8
Sparsely vegetated	8	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.6	0.6

[a] Large trees > 819 mm diameter at breast height (dbh).
[b] Medium trees = 590–819 mm dbh.
[c] Intermediate trees = 385–589 mm dbh.
[d] Small trees = 230–384 mm dbh.
[e] Pole trees = 125–229 mm dbh.

polygons at least 1.2 ha (3 acres) in size and within 0.6 km (0.4 mile) of the road systems at Salt Lake Bay or upper Game Creek were eligible for selection. Also, a 1.2 ha circle needed to fit completely within the polygon. Using GIS software, we randomly selected a sample of polygons meeting the criteria and printed them on digital orthophoto maps. Next, we transferred them to resource photos (1:15,840), using the digital orthophoto maps for reference, and determined compass bearings and distances from known landmarks to the polygon centers. The polygons at den or resting sites were centered on the structure used (Schumacher 1999). The den/resting site polygons were intersected with the size/structure polygon map to determine their composition by mapped landcover strata. Usually these polygons consisted of several pixel types, and we referred to them as mixed-pixel areas. A size/structure map label was assigned to each polygon, based on the labeling rules described by Pacific Meridian (1995).

We measured the structural characteristics for each polygon using a cluster-sampling procedure similar to the USFS GRID project (USFS 1995). Four sample points were established in each polygon. The first sample point was established near the polygon's center. We determined the location of this first sample point by pacing from the edge of the polygon toward its center, a distance equal to the radius of the polygon. Sample point 2 was located 36.6 m north of point 1, point 2 was located on a 120°-azimuth 36.6 m from point 1, and point 4 was located on a 240°-azimuth 36.6 m from point 1. A single, 7.3 m fixed-radius plot was established around each sample point to measure tree, snag, and down wood attributes. For each tree >12.5 cm in diameter (live and dead), we recorded the species, height, diameter (dbh), status (whether live or dead), crown class, and decay category. We noted other habitat attributes such as elevated roots, squirrel middens, extensive cavities, etc. Instead of using transects to measure down wood, we recorded all logs within the plot including its species, length within the plot, diameter of each end, and decay class. Dead trees were considered snags. A single, 5.64-m fixed-radius plot was established around the sample point to measure the understory. The composite cover of each shrub and herb species was estimated along with the average height of the shrub layer. A single, 2.0 m radius fixed plot was established around the sample point to count all seedlings and saplings (trees <12 cm) by species.

For this evaluation, a tree was defined as a live or dead tree greater than 230 mm (9 in.) diameter at breast height (dbh) and taller than 2 m (6.6 ft). Thus, the tree data included live trees and snags, but not stumps. We computed 4 tree size-class variables from the field data for each site. We used the same dbh breaks to create tree size classes as were used to develop the size/structure map classification (Pacific Meridian 1995). We defined large trees as trees/snags greater than 820 mm (32.0 in.) dbh, medium trees were from 590 to 819 mm (23.0–31.9 in.) dbh, intermediate trees from 385 to 589 mm (15.0–22.9 in.) dbh, small trees from 230 to 384 mm (9.0–14.9 in.) dbh, and pole trees 125 to 229 mm (5–9 in.) dbh.

In addition to the above vegetative plots, we estimated total overstory canopy cover by vegetative strata on 56 field plots. These plots were identified for training sites to develop the

LANDSAT TM map classification (Pacific Meridian Resources 1995). At each site, the overstory cover on a 1.2-ha circular plot was visually estimated to the nearest 5%.

Analyses

We defined habitat selection as the ratio of a habitat's proportionate use with its availability (Manly et al. 2002). Selection ratios were computed for each individual marten by dividing its proportionate use of each habitat by its availability in the study area (Manly et al. 2002). In order to compare selection among habitats, we computed a group's geometric mean selection ratio for each habitat and 95% confidence intervals using a weighted bootstrap (Manly 1991). The mean and CI were weighted by the size of the sample contributed by each marten in the group. Martens were grouped by sex (males and females) and season. Marten relocations were grouped into the following seasons: fall = 16 September–15 December; winter = 16 December–15 May; and summer = 16 May–15 September.

We assigned landcover labels to the random sites, using criteria developed by Pacific Meridian Resources (1995). We evaluated map accuracy by comparing the field labels for sites to the map labels, using an error matrix approach (Pacific Meridian 1995). The numbers of exact matches were tallied by landcover strata and expressed as the percentage classified correctly. In addition, an “acceptable” call was assigned to each field site using a fuzzy logic approach described by Pacific Meridian (1995). An acceptable call was given if the site was close (i.e., within 10% canopy cover) to the adjacent category. The numbers of acceptable matches were also tallied by landcover strata and expressed as the percentage classified correctly.

At each site, we summed the number of trees in each size class for the 4 subplots. Thus, the total area sampled at each site was 0.067 ha (0.165 acre), or 5.5% of the 1.2 ha polygon. Descriptive statistics (means and SEs) for the tree size-class variables were computed for each stratum. Separate sets of statistics were calculated for the random sites, den/rest sites, and combined data sets. The random and den/rest sites were compared with a series of *t*-tests of the tree-class variables by strata. Because none of the strata were significantly different (alpha = 0.05) between the site type for any tree-class variable, the random and den/rest sites were pooled for the rest of the analyses. In addition, the Shrub, Clearcut, and Sparsely Vegetated strata were combined into a single, Nonforest stratum because these strata had few trees.

Differences among size/structure strata were evaluated for each tree size-class variable using a series of one-way analysis of variance tests (ANOVA; Snedecor and Cochran 1980). We tested the hypothesis that the means or a tree-class variable were the same for all the map strata. If at least 1 of the strata were significantly different based on the ANOVA (alpha < 0.05), then we used Tukey’s studentized range test (ANOVA post-hoc analysis) to determine which strata differed (alpha = 0.1) for the tree size class. This analysis identified the map strata that were statistically different for at least 1 tree size-class variable. In addition, we identified the variable means that were significantly different for the comparison. The means of additional measures of forest structure were compared among strata using a similar approach. These measures included overstory canopy cover, the number and size of vertical boles, and the amount and size of logs.

We tested the habitat coefficients in the interagency habitat capability model (Suring et al. 1993) by comparing habitat selection indices with the coefficients in the habitat model (Schamberger and O'Neil 1984). For this comparison, we took the computed habitat selection indices for all animals during the winter/spring season and scaled them to range from 0.0–1.0. We compared the 95% CI for the habitat selection indices with the values in the habitat capability model. If the 95% CI overlapped for a habitat, we concluded that no evidence existed to indicate the model coefficients were incorrect. Because we used the landcover map derived from LANDSAT TM imagery for the test, the habitat categories were not an exact match with those used in the habitat capability model derived from the USFS's timber-type coverage (Caouette and DeGayner 2008). Thus, we developed the following cross-reference between the mapped landcover categories: Large/MS = high timber strata (>30,000 board-feet/acre), Medium/MS = medium timber strata (20,000–30,000 board-feet /acre), Intermediate/MS = low strata forest (8,000–20,000 board-feet /acre), Small/MS = unproductive forest, and Shrub and Sparsely Vegetated = nonforest.

Results

Habitat Selection

On the primary study areas, we located 137 radiocollared martens (86 males and 51 females) 2,978 times to determine habitat selection. On northeast Chichagof Island, martens primarily used forested habitats (82%) (Fig. 3). They made little use of Shrub (7.5%), Clearcuts (6.8%), or Sparsely Vegetated habitats (4.2%). Among forested habitats, the Medium/MS (28.6%) habitat had the greatest use followed by Large/MS (18.9%) and Intermediate/MS (18.5%). Small/MS (12.4%) and Singlestoried (3.0%) had limited use.

Martens showed the greatest selection for large- (selection ratio = 1.39) and medium-sized MS stands (selection ratio = 1.30) (Fig. 3). The mean selection ratios of these 2 habitats were not significantly different from each other, but both were significantly greater than any other habitat. Intermediate/MS stands (1.11) were selected less than the larger-sized habitats, but more than Small/MS (0.72), Singlestoried (0.81), and nonforested sites (Shrub = 0.20 and Sparsely Vegetated = 0.30).

For male martens, habitat selection ratios were similar to the pooled values previously described (Fig. 4). Because of reduced sample sizes, more of the 95% CIs overlapped. Still male martens preferred large-sized stands (Large/MS = 1.50 and Medium/MS = 1.30) compared with Intermediate/MS (1.12) and smaller-sized habitats (Small/MS = 0.66).

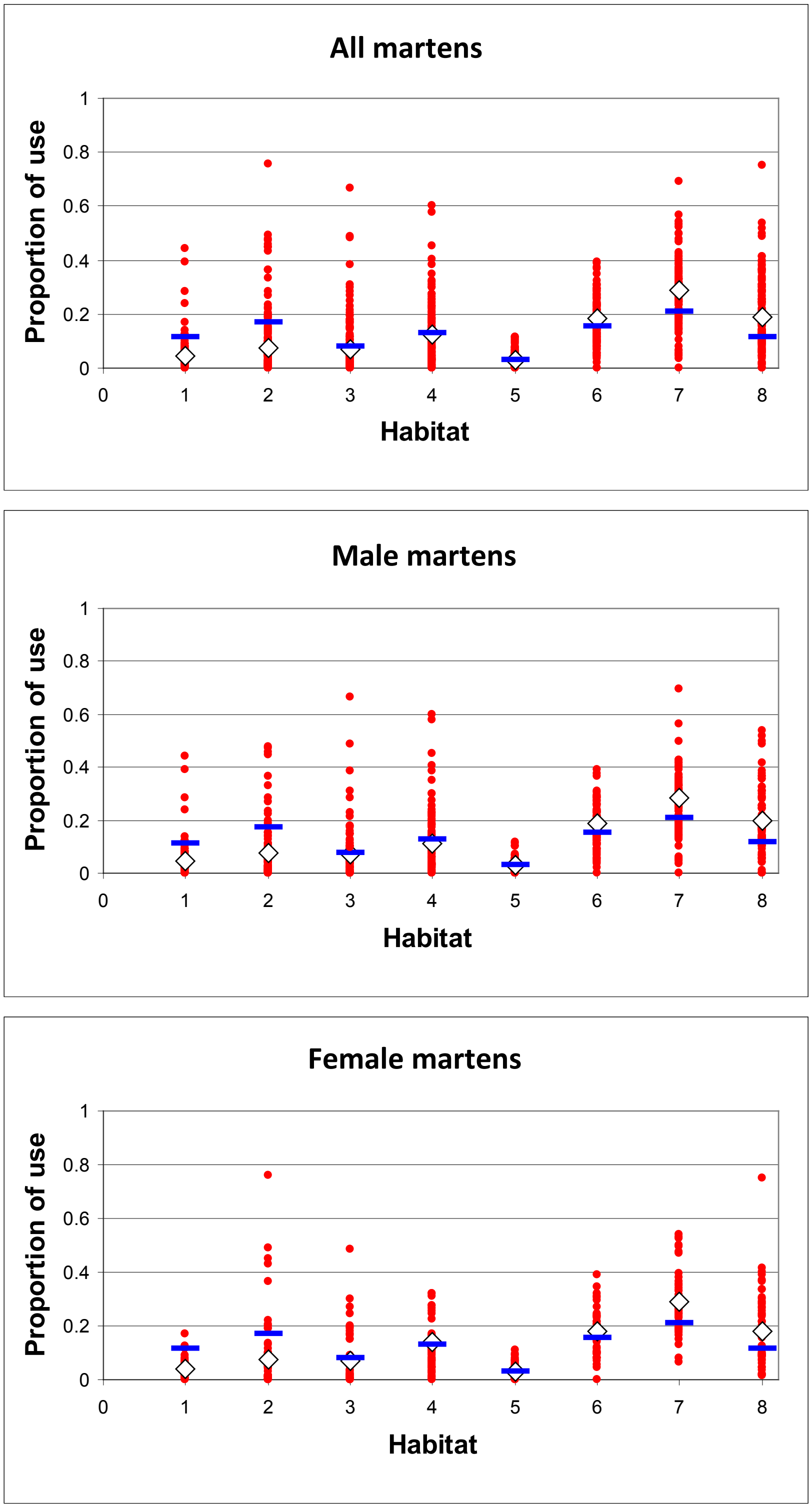

Figure 3. Habitat use by martens on northeast Chichagof Island. The diamonds represent the mean use for each habitat and each dot represents the use by 1 animal. The line indicates habitat availability. Habitats are as follows: 1 = Nonforest, 2 = Shrub, 3 = Clearcut, 4 = Small/MS, 5 = Singlestoried, 6 = Intermediate/MS, 7 = Medium/MS, and 8 = Large/MS.

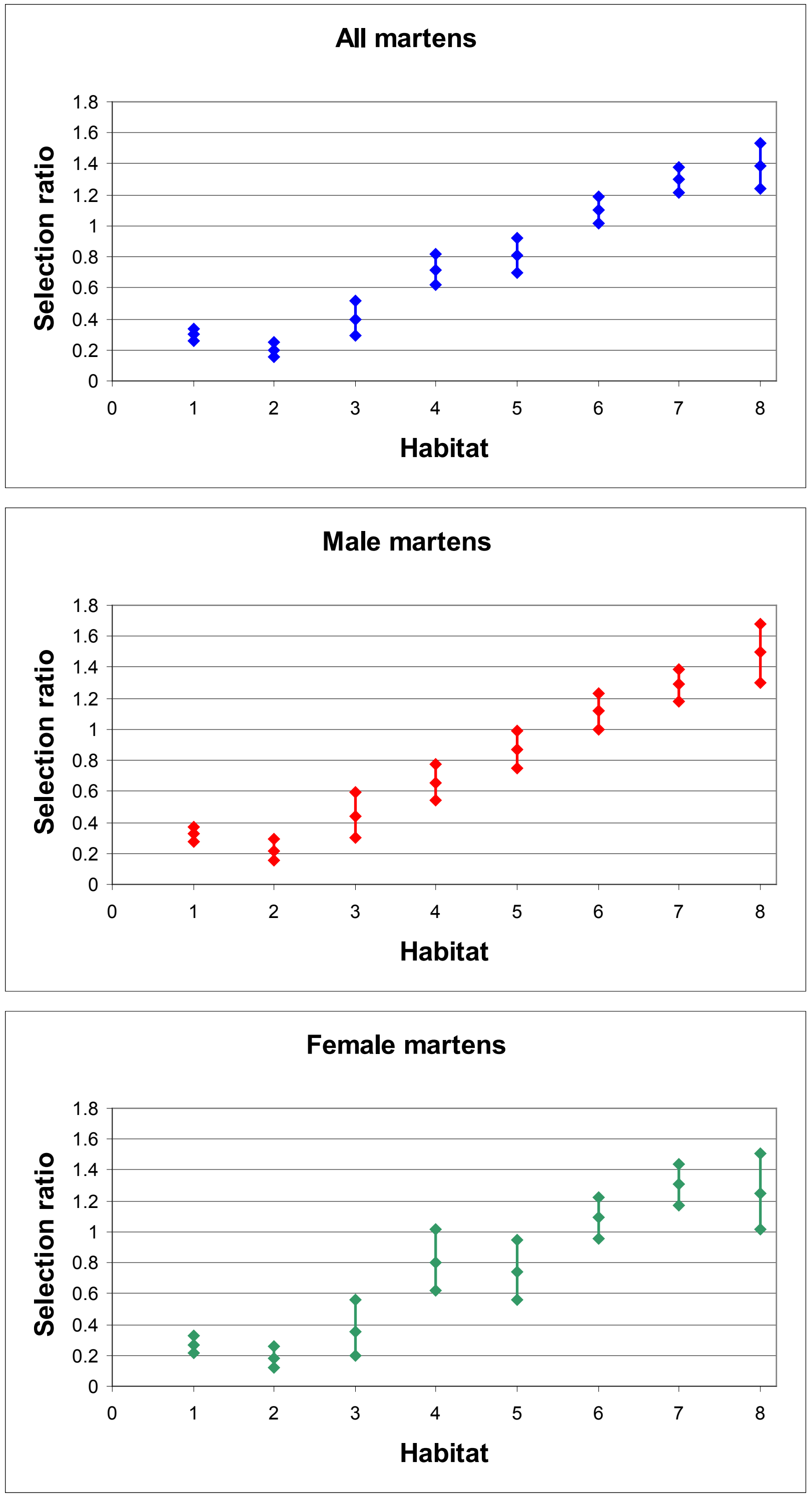

Figure 4. Habitat selection ratios and 95% CIs for martens on northeast Chichagof Island by sex. Habitats are as follows: 1 = Nonforest, 2 = Shrub, 3 = Clearcut, 4 = Small/MS, 5 = Singlestoried, 6 = Intermediate/MS, 7 = Medium/MS, and 8 = Large/MS.

Although patterns were similar, female martens showed somewhat more variability in habitat selection than males (Fig. 4). Thus, fewer significant differences were found. Selection by females for Intermediate/MS habitat (1.10) was not significantly different from Large/MS (1.25) and Medium/MS (1.31).

Martens showed the greatest selection for habitats during the winter season (Fig. 5). Selection ratios for Large/MS and Medium/MS-habitats were similar (1.53 and 1.40), but greater than all other types. Nonforest habitat (0.18), including Clearcuts (0.36), had small selection ratios during the winter. Intermediate/MS (1.01), Singlestoried (0.75), and Small/MS (0.56) habitats were in between. During summer, marten selection ratios were similar for Large/MS (1.17), Medium/MS (1.21), and Intermediate/MS (1.00) habitats, but these habitats had larger ratios than all others. During fall, selection ratios were similar for all of the forested habitats, but these differed from the nonforested types. Thus, martens showed the largest selection among forested habitats during the winter followed by summer. During the fall, little selection was observed among forested habitats. Selection ratios for Nonforest habitats were always small confirming a general avoidance of Nonforest by martens.

HABITAT ATTRIBUTES

For 65 random sites, the field label exactly matched the map label 55 times (85%). For only forest strata, the exact match was 78% (32 of 41). In each of the mismatches, the labels differed by only 1 size class. We found the poorest accuracy within the Medium/MS (exact = 63%) and Intermediate/MS (exact = 67%) strata. These strata appeared to be the most variable and difficult to map accurately. Fehringer (1997) also found relatively low map accuracy for the Intermediate/MS type (acceptable = 63%). Additional plots are needed in these types to better determine whether they are good landcover types. The Nonforest and Small/MS strata were nearly 100% accurate. The LANDSAT TM procedures appeared to map these types well. Generally, we found greater overall map accuracy than reported by Pacific Meridian Resources (1995) and Fehringer (1997). We may have found greater map accuracy because our random sites were selected from homogenous areas greater than 1.2 ha. In addition, our sites were field-visited and tree attributes were measured. The accuracy assessment sites selected for the original pilot project (Pacific Meridian Resources 1995) and supplemented by Fehringer (1997) were generally more heterogeneous than our sites. Our data indicated that the LANDSAT TM mapping procedures classified larger (>1.2 ha), homogenous areas more accurately than heterogeneous areas. Also, the polygon labeling rules for mixed-pixel areas may need additional evaluation.

The landcover strata were significantly different for tree-class variables (ANOVA, alpha = 0.05). Because of the numerous comparisons, we summarized the landcover strata that differed by tree class variable (Tables 1–3). Generally, Large/MS sites had more large trees and fewer intermediate and small trees. Medium/MS sites were well stocked with many trees of all size classes.

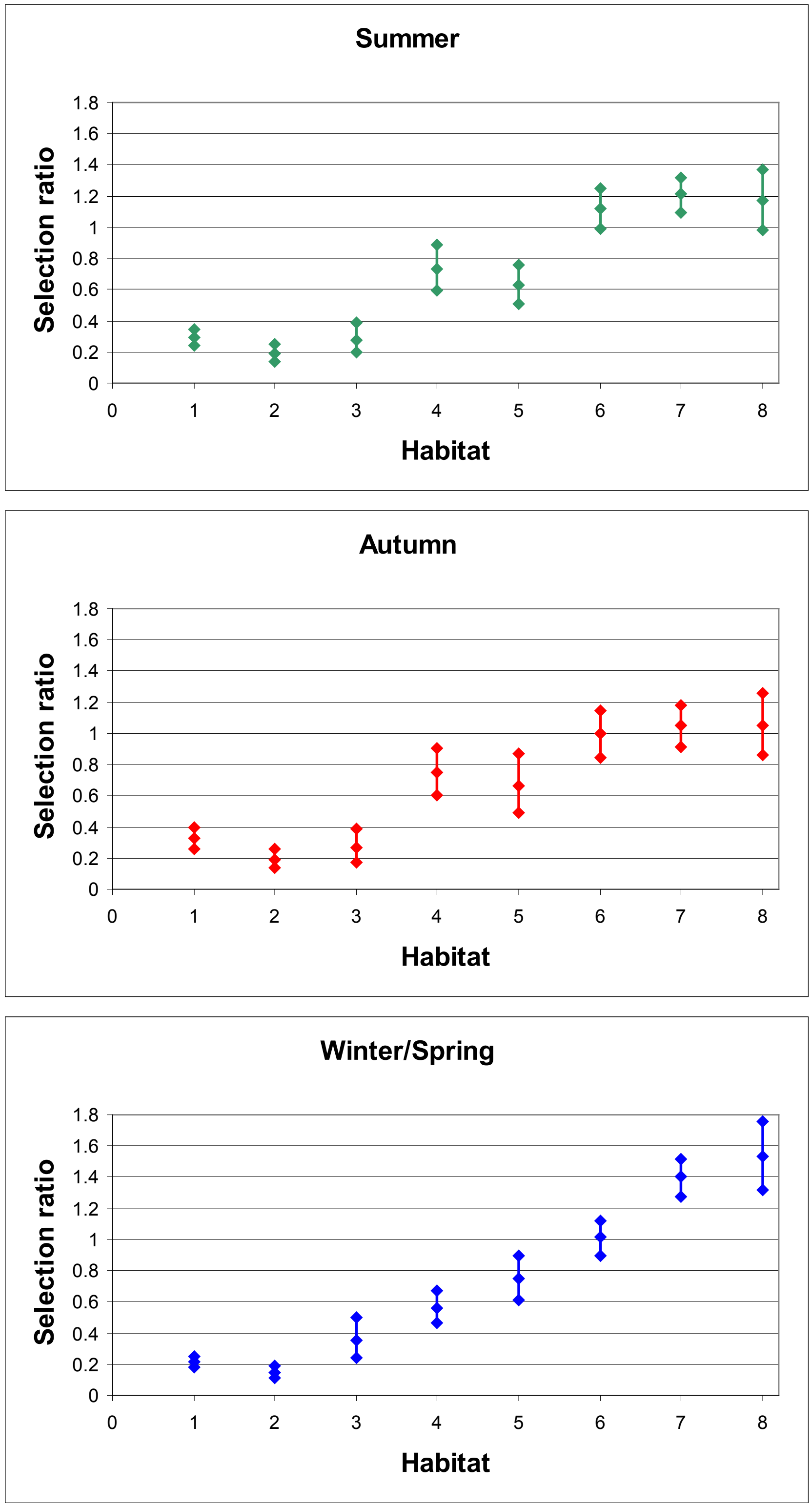

Figure 5. Seasonal habitat selection ratios and 95% CIs for martens on northeast Chichagof Island. Habitats are as follows: 1 = Nonforest, 2 = Shrub, 3 = Clearcut, 4 = Small/MS, 5 = Singlestoried, 6 = Intermediate/MS, 7 = Medium/MS, and 8 = Large/MS.

Table 2. Mean numbers of trees/plot by tree-size class for each map strata on northeast Chichagof Island, Southeast Alaska, 1996–1998. All map strata differed significantly for at least one tree-class variable (ANOVA, alpha = 0.01). Habitat map data was from LANDSAT TM imagery.

Tree class variable[a]	Strata Means				
Number large trees					
Large/MS[b]	Medium/MS	Intermediate/MS	Small/MS	SS	NF
2.8 A	2.3 AB	1.3 BC	0.5 CD	0.4 CD	0.0 D
Number medium trees					
Medium/MS	Large/MS	Intermediate/MS	SS	Small/MS	NF
3.0 A	2.8 AB	2.6 AB	1.9 ABC	1.5 BC	0.0 C
Number intermediate trees					
SS	Intermediate /MS	Medium /MS	Small/MS	Large/MS	NF
9.0 A	6.0 AB	5.8 AB	4.3 B	3.9 B	0.1 C
Number small trees					
SS	Small/MS	Intermediate/MS	Medium/MS	Large/MS	NF
22.2 A	12.6 B	10.4 BC	8.3 CD	6.2 D	0.4 E
Number pole trees					
SS	Small/MS	Intermediate/MS	Medium/MS	Large /MS	NF
32.1 A	17.2 B	14.9 BC	13.6 BC	7.8 C	1.0 D

[a] Tree classes defined are as follows: large trees = number of trees > 820 mm diameter at breast height (dbh); medium trees = number of trees 590–819 mm dbh; intermediate trees = number of trees 385–589 mm dbh; small trees = number of trees 230–384 mm dbh; pole trees = number of trees 125–229 mm dbh.

[b] Strata means within rows followed by the same letter were not significantly different (Tukey's studentized range test, alpha = 0.1).

Table 3. Means of vegetative characteristics for each map strata on northeast Chichagof Island, Southeast Alaska, 1996–1998. All map strata differed significantly for at least one tree variable (ANOVA, alpha = 0.01). Habitat map data was from LANDSAT TM imagery.

Tree variable[a]	Strata Means					
Tree height (m)						
	Large/MS	SS	Medium/MS	Intermediate/MS	Small/MS	NF
	24.7 A[b]	22.6 AB	20.4 B	19.2 B	14.5 C	1.9 D
QMD (cm)						
	Large /MS	Medium/MS	Intermediate/MS	Small/MS	SS	NF
	63.3 A	57.0 B	50.4 BC	40.9 BC	39.4 C	9.1 D
Basal area (m^2)						
	Large/MS	Medium/MS	SS	Intermediate/MS	Small/MS	NF
	5.03 A	4.80 AB	4.19 AB	3.93 AB	2.57 B	0.19 C
Basal area of TSHE (m^2)						
	SS	Large /MS	Medium/MS	Intermediate/MS	Small /MS	NF
	2.84 A	2.58 AB	2.00 BC	1.47 C	0.41 D	0.04 D
Basal area of CHNO (m^2)						
	Small /MS	Medium /MS	Intermediate /MS	Large/MS	NF	SS
	1.00 A	0.70 A	0.61 AB	0.08 BC	0.02 C	0.0 D
Basal area of TSME (m^2)						
	Intermediate/MS	Medium/MS	Large /MS	Small/MS	SS	NF
	0.51 A	0.50 A	0.49 A	0.48 A	0.16 B	0.01 C

[a] Includes all live and dead tress > 229 mm DBH and >2 m in height. QMD = quadratic mean diameter, TSHE = *Tsuga heterophylla*, CHNO = *Chamaecyparis nootkatensis,* TSME = *Tsuga mertensiana*..

[b] Strata means within rows followed by the same letter were not significantly different (Tukey's studentized range test, alpha = 0.1).

Intermediate/MS sites were highly variable. Some sites had clumps of larger trees mixed with intermediate and small trees. Some Intermediate/MS sites had only intermediate and smaller trees. Also, several of the Intermediate/MS sites were misclassified; these sites added substantial variance to data for this stratum. Small/MS sites had few large trees and numerous small trees.

Some of the differences were obvious. The Nonforest stratum had few trees of any size and differed from most other forest strata for nearly all variables. The Singlestoried sites differed from all others because of the large number of intermediate and small trees present. Four of the Singlestoried sites resulted from natural wind throw, three resulted from about 35-year-old clearcuts, and 1 was a misclassified small stand.

The magnitude of the differences among means was large in some cases, but the differences were not statistically significant because of large variances or small sample sizes. The Intermediate/MS stratum was the most variable and not different from Medium/MS or Small/MS strata. The other multistory strata were different for at least 1 tree-class variable. Large/MS differed from Medium/MS (fewer intermediate trees), Intermediate/MS (more large trees), and Small/MS for 2 variables (more large trees, fewer small trees). Medium/MS was also different from Small/MS (more large and intermediate trees).

For forested sites, the mean size of logs reflected the vertical boles across the strata ($r = 0.94$) (Table 4). Thus, the Large/MS and Medium/MS stands had the largest logs compared with the other strata. Although the number of logs was correlated with the number of vertical boles ($r = 0.64$), the relationship was weaker, mostly because the Small/MS and Singlestoried stands had lots of boles but relatively few logs. The Clearcut strata had the greatest number of logs and a substantial greater mean log area.

The amount of overstory canopy cover followed the same trend as the tree characteristics (Table 5). Singlestoried stands had nearly a closed overstory canopy (95.4%). The Large/MS strata was next (79%) followed by Medium/MS (72.7%), and Intermediate/MS (64.0%). The Small/MS (45.2%) stands were relatively open.

Habitat Capability Model

The 95% confidence intervals (CIs) for the observed marten selection indices overlapped with the values in the original model, except for Singlestoried (Table 6). The original model assigned a value of 0.1 to this habitat, but the observed scaled selection index was 0.49 (CI = 0.40–0.57). Most of the stands mapped as Singlestoried resulted from wind disturbance instead of clearcut logging. We found little use by martens of Singlestoried stands that had regenerated following clearcut logging. Most of the use was in mixed stands of regenerating conifer and alder. Thus, the 0.1 coefficient would still be appropriate for closed-canopy, singled-storied stands resulting from regenerating clearcuts and a value of 0.49 for other singled-storied stands.

Table 4. Means (SE) for selected attributes of 5 forested habitat strata and 1 clearcut habitat stratum identified from LANDSAT TM imagery on northeast Chichagof Island, Southeast Alaska, 1996–1998.

	Strata						
Variable	Large/ MS	Medium/ MS	Intermediate/ MS	Small/ MS	Single-storied	Clearcut	Study area
Vertical boles							
AVGDBH[a]	47	39	35	25	30	52	38
(cm)	(3.9)	(3.6)	(3.4)	(1.3)	(1.2)	(3.9)	(3.2)
NOBOLES[b]	487	591	669	572	1133	400	588
(boles/ha)	(59.7)	(42.9)	(83.5)	(98.2)	(134.4)	(63.9)	(70.3)
SUMBA[c]	1114	948	769	403	1053	1038	854
(m^2/ha)	(100.9)	(126.2)	(102.4)	(102.9)	(116.3)	(110.2)	(110.6)
Logs							
AVGDMLG[d]	40	39	35	32	32	30	36
(cm)	(2.0)	(2.8)	(3.1)	(2.5)	(1.8)	(2.0)	(2.6)
MAXDMLG[e]	100	89	81	47	116	96	83
(cm)	(9.7)	(10.9)	(15.1)	(4.8)	(30.8)	(10.9)	(11.3)
NOLOGS[f]	337	303	251	134	434	711	317
(logs/ha)	(41.2)	(45.5)	(31.2)	(30.9)	(85.3)	(56.0)	(42.0)
SUMLOGAR[g]	539	399	309	206	660	1141	460
(m^2/ha)	(107.6)	(86.4)	(55.2)	(57.2)	(267.3)	(158.2)	(93.2)

[a] Mean dbh of vertical boles >12 cm dbh and > 0.2 m tall.
[b] Number of vertical boles >12 cm dbh and > 0.2 m tall.
[c] Sum of basal area of vertical boles >12 cm dbh and >0.2 m tall.
[d] Mean diameter of the large end of logs>12 cm diameter and .0.9 m long
[e] Maximum diameter of logs >12 cm diameter and >0.9 m long.
[f] Number of logs >12 cm diameter and >0.9 m long.
[g] Sum of area (midpoint diameter * length) of logs >12 cm diameter and >0.9 m long

Table 5. Overstory canopy cover of forested size classes by LANDSAT TM size strata for all sites, northeast Chichagof Island, Southeast Alaska, 1996–1998. Sparsely Vegetated and Shrub strata had little overstory canopy cover.

	No.	Canopy cover (%)	
Landcover strata	plots	$\bar{x}$	SE
Singlestoried	5	95.4	1.47
Large/MS	11	79.0	4.53
Medium/MS	15	72.7	3.08
Intermediate/MS	13	64.0	3.04
Small-pole/MS	4	45.2	1.89
Clearcut	6	2.7	1.20

Table 6. Comparison of habitat selection coefficients and the coefficients in the habitat capability index model for martens including a crosswalk between landcover maps.

	Selection ratios[a]			
Landcover strata	Ratio	CI	HCI model[b] categories	HCL model coefficients
Large/MS	1.00	0.86–1.12	>30, 000	1.0[c]
Medium/MS	0.91	0.83–0.98	20–30,000	0.9[c]
Intermediate/MS	0.66	0.58–0.72	8–20,000	0.7[c]
Small-pole/MS	0.37	0.30–0.42	<8,000	0.3[c]
Clearcuts	0.23	0.16–0.30	Seedling/sapling	0.2[c]
Singlestoried	0.49	0.39–0.57	Young growth	0.1

[a] Selection ratios scaled to range from 0–1.0.

[b] Habitat category crosswalk. HCI model categories based on timber-type volume classes (board-foot/acre net inventory volume).

[c] 95% CIs of selection ratios overlapped with model coefficients.

Discussion

Habitat Selection

We found that martens used mostly multistoried, old-growth conifer forests (82%) and selected for forest stands with larger-sized trees and abundant structure within a coastal temperate rainforest landscape. They made little use of the other available habitats, including Sparsely Vegetated sites, Shrub fields, Clearcut, or regenerated clearcuts. Our findings were consistent with other marten habitat studies across North America (Buskirk and Ruggiero 1994) and especially in the western regions (Koehler et al. 1990, Jones and Raphael 1992, Raphael and Jones 1997, Bull and Heater 2000, Koch 2016). All of these studies have found martens limited to conifer-dominated forests, usually late-successional stands on mesic sites (Buskirk and Ruggiero 1994). Often, these forests contained abundant and complex physical structure, including large live trees, snags, and down wood.

Martens showed the greatest selection for Large/MS and Medium/MS stands. The mean selection ratios of these 2 habitats were not significantly different from each other, but both were significantly greater than any other habitat. Intermediate/MS stands (1.11) were selected less than the larger-sized habitats, but more than Small/MS (0.72), Singlestoried (0.81), and nonforested sites (Shrub = 0.20 and Sparsely Vegetated = 0.30). Intermediate/MS stands often contained small patches of large boles within a generally smaller-sized stand (Schumacher 1999). Live trees in a larger old-growth stand frequently contained substantial decay, which resulted in numerous cavities. These woody structures provided excellent den and resting sites (Schumacher 1999) and cover from the wet weather and potential predators.

Martens showed the largest selection among forested habitats during the winter followed by summer. During the fall, little selection was observed among forested habitats. Selection ratios for nonforest habitats were always small, confirming a general avoidance of nonforest by martens. During the colder temperatures of winter, martens may need to rest in cavities available in larger woody structures of large-sized stands (Schumacher 1999). Winter conditions in Southeast Alaska are often characterized by frequent rain and wet snow conditions, exposing martens to thermal stress (Harlow 1994, Wilbert et al. 2000). Large woody debris may provide important cover from the elements while traveling or hunting (Taylor and Buskirk 1994). Also, large conifer trees intercept snow (Kirchhoff and Schoen 1987), perhaps resulting in prey being more available under the canopy. Also, winter habitats selected by martens were similar to those of Sitka black-tailed deer (Schoen and Kirchhoff 1985). Apparently, martens seek these habitats to scavenge on deer carcasses (Ben-David et al. 1997), especially in deep snow winters.

We found that the stands selected by martens had abundant woody structure and a greater overstory canopy. The highest selected Large/MS habitat category had the greatest number of large trees, the tallest trees, greatest mean QMD, and largest logs. Typically, the Medium/MS stands had less structure followed by Intermediate/MS stands. Conversely, the small-sized stands had few large trees or logs. The Singlestoried stands had a large number of vertical boles, but the mean QMD was significantly smaller. Also, these stands had a large number of logs, but the mean diameter was small. The large number of boles resulted in a nearly closed canopy with little understory. Selected stands had a mean overstory canopy > 72.2% with a range of 52–95%. Avoided stands were either open (Small/MS, canopy cover range 42–49%) or tightly closed Singlestoried. The overstory canopy cover of unselected Intermediate/MS stands was relatively more open and variable, ranging from 40–75%.

Other studies have found that larger-sized stands on productive sites in the temperate rainforest provide an abundance of woody structure, including live trees, snags, and logs, all in close proximity (Alaback and Juday 1989, Schumacher 1999, Koch 2016). This combination of woody structure probably best meets martens' life history requirements and provides the most suitable habitat. Because of the available structure in these forests, a variety stands were used by martens, especially during the warmer seasons. Although recent clearcuts were avoided, they did receive some use, probably because of the abundance of large logs. Schumacher (1999) found some dens and resting sites in clearcuts, especially near the forest edge. Large trees and CWD provide martens with several important life history requirements including cover from predators (Vernam 1987, Lindstrom et al. 1995), shelter from inclement weather while resting (Buskirk et al. 1989, Martin and Barrett 1991), denning sites (Hauptman 1979, Wynne and Sherburne 1984, Baker 1992, Ruggiero et al. 1998), and suitable forage (Corn and Raphael 1992, Flynn and Schumacher 2009). Adequate availability of structures for denning and resting is probably important for marten survival (Henry and Ruggiero 1993, Raphael and Jones 1997).

Koch's (2016) recent study on Kuiu Island in Southeast Alaska, where extensive clearcutting has occurred, found that martens selected habitats with taller trees, nearer to salmon-spawning streams, and closer to the ocean shoreline. Also, Koch (2016) truncated his available habitat at 500 m because he found less than 5% of his locations above this elevation. Koch (2016) found demography plays a role in habitat selection on Kuiu Island. Juvenile martens selected habitats with higher salmon-spawning stream densities than adults. In contrast, adult females used habitat further from the coast with lower densities of salmon streams. Also, Koch (2016) found that in the year with the highest abundance of martens and proportion of juveniles, all martens used habitats with higher densities of salmon-spawning streams. On Chichagof Island during the same period (1991–1998), Flynn and Schumacher (2009) found the marten population fluctuated greatly with changes in prey, especially long-tailed voles. In the present study, we didn't analyze changes in habitat selection due to demography; but Chichagof Island, unlike Koch's study area on Kuiu, has low densities of salmon-spawning streams and the whole Chichagof study area was close to the ocean shoreline.

HABITAT CAPABILITY MODEL

The habitat selection data collected during this study were consistent with the values in the original habitat capability model (Suring et al. 1993). Generally, the 95% confidence intervals (CIs) for the observed marten selection indices overlapped with most of the values in the original habitat capability model. The poorest fit was for the Singlestoried category. The original model assigned a value of 0.1 to this habitat based on the habitat characteristics of regenerated clearcuts. The observed scaled selection index was 0.49 (0.40–0.59). We suspect that the LANDSAT TM map included a wider range of singlestoried forest types than the original habitat model. The relative habitat value of regenerated clearcuts is probably more similar to the original model values. Also, the original model gave no value to nonforest types, but these types had selection indices that did not include 0. We suspect that sometimes the martens used small patches of forest mapped as Nonforest.

Management Implications

In the temperate rainforests of Southeast Alaska, martens selected for larger-sized, multistoried coniferous forested habitats typical of productive, old-growth coniferous forests. Little use was recorded for small-sized forest stands or nonforest habitats. The selected habitats had abundant woody structure, both vertical and on the ground. Clearcut logging removes most of the overstory structure in the harvest unit. Although an abundance of CWD may exist immediately after clearcutting, the amount and size of CWD will decline as the slash and residual CWD decay (Franklin and Waring 1980, Tritton 1980). Also, the lack of overstory cover greatly reduces the habitat value. With a planned 100-year timber rotation, managed forests will not develop large woody structures whether vertical live trees and snags or CWD before the next cutting (USFS 1997).

In order to maintain healthy marten populations on the TNF, land managers need to provide sufficient habitat to support productive populations. Martens need habitats that provide the proper combination of available food, cover from the elements, and protection from predators. We know that productive, old-growth forests best provide for these habitat requirements along the north Pacific Coast and Southeast Alaska. The retention of large blocks of preferred habitats should ensure the maintenance of healthy populations. In logged stands, a substantial amount of vertical structure will need to be left in the harvest units to retain habitat value for martens, especially during the winter. Although little research has been done on selective logging approaches in Southeast Alaska (Deal 2001), new silvicultural systems that use partial cutting could provide a sustainable timber resource while maintaining some stand structural diversity (Deal and Tappeiner 2002). These approaches have had success in other regions (Sturtevant et al. 1996, Leiffers and Woodward 1997). Unfortunately, we were unable to include any selectively logged stands in our study because none existed in our study area. Additional research is needed to examine the impact of selective structure removal on marten habitat. In addition, recent studies have found that increased forest fragmentation reduced habitat value for martens (Chapin et al. 1998, Hargis and Bissonette 1997, Hargis et al. 1999, Bissonette et al. 1997. Thus, the effects of the distribution of habitats across the landscape need additional study.

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