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ABUNDANCE, PREY AVAILABILITY AND DIETS OF AMERICAN MARTENS: IMPLICATIONS FOR THE DESIGN OF OLD-GROWTH RESERVES IN SOUTHEAST ALASKA

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Contents

Abstract: Under the Tongass Land Management Plan (TLMP), the U.S. Forest Service is required to leave old-growth reserves that will support viable American marten (*Martes americana*) populations. Specifically, TLMP states that large Old Growth Reserves (OGRs) should support a minimum of 25 female martens. We estimated marten densities at 8 sites throughout Southeast Alaska and projected the number of females in a 16,200 ha OGR. From September 2001 to December 2003, we captured 85 individual martens (50 M, 35 F) from 1–3 times in 8 study areas. Capture rates varied widely among areas with the highest capture rates on Chichagof Island and Thomas Bay, and the lowest capture rates at the Kuiu and Etolin Islands. Marten densities were lower than expected in most areas. Point estimates for numbers of females inhabiting a large OGR were less than the 25 assumed in TLMP at all study areas except Chichagof Island. Point estimates for Point Couverden and Thomas Bay were 19 and 15 females, respectively. Estimates for the remaining 5 study areas ranged from 4–10 females in a large OGR. Although estimates were relatively imprecise, 80% confidence limits included 25 females at only 3 study areas.

Studies of martens conducted on northeast Chichagof Island from 1991-1998 found that marten diets varied seasonally and annually, especially in response to small rodent numbers. On northeast Chichagof martens fed on voles during periods of high abundance, but switched to feed on seasonally available salmon (*Oncorhynchus* spp.) when vole numbers were low. Nonetheless, on northeast Chichagof Island, the number of potential alternative mammalian foods for martens is relatively limited (i.e., long-tailed vole (*Microtus longicaudus*), Keen's mouse (*Peromyscus keeni*), and red squirrels (*Tamiasciurus hudsonicus*). In this study, we explored whether martens inhabiting geographic areas with higher diversity of potential foods such as other islands and mainland sites in the Alexander Archipelago would exhibit different dietary patterns. Using stable isotope analysis of blood samples taken from live-captured martens and muscle samples concurrently collected from trapped small mammals, we determined that the pattern observed on Chichagof Island applies to other locations in the Tongass. Our results suggested that marten populations on different islands in the Tongass National Forest rely heavily on long-tailed voles. Where vole numbers were low, salmon was the main source of food for martens during fall even in areas where prey diversity was higher than on Chichagof Island. The threshold of vole abundance at which martens switched to feed on salmon was about 1 vole per 100 trap-nights. Also, we determined that when vole numbers were low and both mice and salmon were available, martens fed on salmon. Nonetheless, the low densities of martens in our study areas that included salmon streams suggested that availability of alternative foods at other times of year such as ungulate carrion could also influence survival and reproduction in these carnivores.

Because the assumptions made in TLMP regarding the minimum number of females in OGRs may not be met in most areas, the efficacy of the conservation measures for martens in the Forest Plan needs additional consideration. For populations of martens where OGRs and lands in other non-development land use designations (LUDs) are unlikely to support a sufficient number of females and where further timber harvest is planned, additional conservation measures may be necessary. Increasing the size and proportion of higher quality habitat of OGRs would likely result in higher density of martens in individual OGRs. Because of the apparent importance of salmon as an alternate food in years of low vole abundance, the inclusion of salmon streams within OGRs may increase carrying capacity for martens. Therefore, the U.S. Forest Service should insure the inclusion of salmon-spawning streams in old-growth reserves. Finally, increased connectivity among OGRs would increase the likelihood that populations function as metapopulations and would be repopulated by immigration after local extinctions have occurred. On islands where marten numbers are low, allocating wider corridors between OGRs than required by TLMP may enhance dispersal and therefore viability of marten population. Also, roads through corridors may reduce their effectiveness because fur trappers often use roads to target animals. Finally altering harvest practices may improve the dispersal matrix and facilitate the existence of meta-populations. For example, yarding logs by helicopter would reduce the need to build roads, partial harvest instead of clearcutting could maintain higher habitat value for martens and voles, and clumping timber harvest would reduce the fragmentation of the remaining habitat.

Key words: abundance estimation, American marten, conservation strategy, diet relationships, *Martes americana*, old-growth reserves, small mammals, Southeast Alaska, stable isotope analysis, Tongass National Forest

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INTRODUCTION

The conservation strategy of the Tongass Land Management Plan (TLMP) emerged from the principles of metapopulation theory (U.S. Forest Service 1997). A metapopulation is defined as groups of conspecifics (or populations) that are distributed over patches of suitable habitat, spatially isolated by a matrix of unsuitable habitat, which could be crossed but could not support resident animals (McCullough 1996). A metapopulation may persist over time if extinctions of local populations are not synchronized, and extirpated areas can be recolonized from other adjacent populations (Hedrick 1996). Connectivity of suitable habitat patches is important for maintaining the viability of the metapopulation through dispersal (McCullough 1996).

Under the direction of metapopulation theory, the TLMP conservation strategy created a matrix of old-growth reserves (OGRs) of various sizes, shapes, and spacings (Fig. 1). Several species were identified as “design” species based on their dependency on forested habitats and the assumption that their preservation will also facilitate the long-term persistence of other species in the assemblage, including other terrestrial mammals and migratory birds (Buskirk 1992, Suring et al. 1993). Those species included, among others, the northern flying squirrel (*Glaucomys sabrinus*) as an indicator for small (< 4,047 ha) old-growth reserves, American martens (*Martes americana*) as an indicator of medium size reserves (4,047 – 16,200 ha), and wolves (*Canis lupus*) and bears (*Ursus* spp.) as indicators of large old-growth reserves (> 16,200 ha; U.S. Forest Service 1997). In developing the conservation strategy 2 assumptions were made: 1) OGRs will be sufficient to support well-distributed, viable populations and 2) the harvested matrix will provide habitats that will allow for dispersal of individuals among the old-growth reserves. These assumptions, however, were not previously tested.

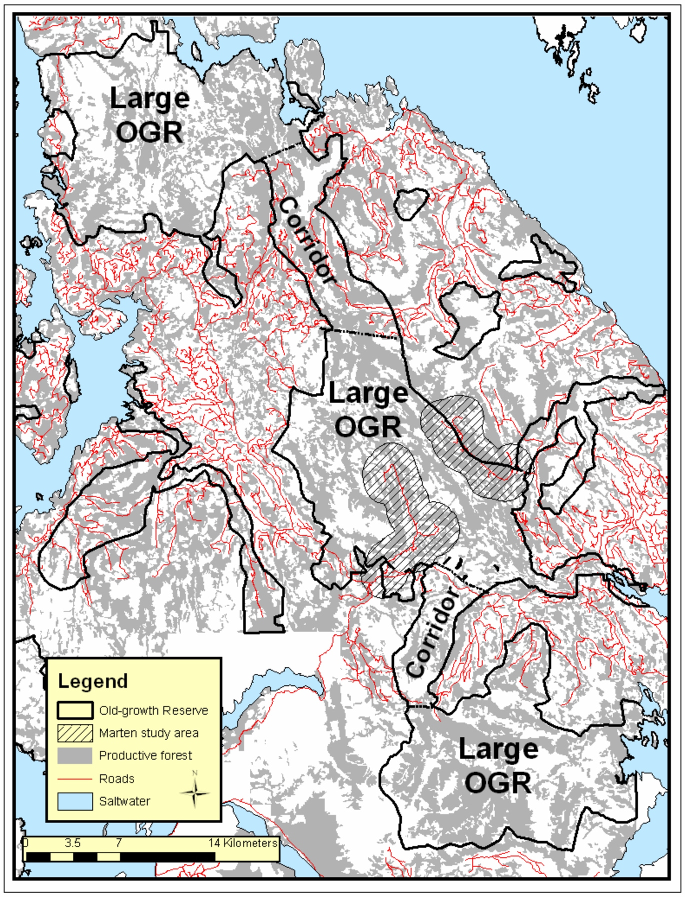

Figure 1. Our interpretation of the old-growth reserve system on central Prince of Wales Island based on an examination of the layout of lands in non-development Land Use Designations (LUDs) (U.S. Forest Service GIS database).

American martens were chosen as one of the design species in TLMP because they exhibit a consistent close association with mature forests throughout their distributional range (Snyder and Bissonette 1987, Buskirk 1992, Thompson and Curran 1995, Sturtevant et al. 1996). Mature, closed canopy stands confer thermoregulatory advantages that can enhance winter survival (Harlow 1994, Taylor and Buskirk 1996, Wilbert et al. 2000). In addition, the high structural complexity of old-growth forests influences availability of den and resting sites, food availability, and foraging success (Buskirk and Ruggiero 1994, Sherburne and Bissonette 1994, Taylor and Buskirk 1994, Ben-David et al. 1997, Chapin et al. 1997, Ruggiero et al. 1998, Wilbert et al. 2000), as well as providing protection from predation (Hodgeman et al. 1997, Leiffers and Woodward 1997). Indeed, the strong association between *Martes* species and forested habitats can also be seen in the fossil record (Powell 1981, Clark et al. 1987, Graham and Graham 1994). In addition, marten pelts represent significant economic value to local residents, and thus have added significance for multiple use management of the Tongass National Forest (TNF).

Industrial forestry practices have resulted in fragmentation of mature forests throughout North America (Buskirk and Ruggiero 1994). Timber harvest of old growth high and low volume stands, particularly the clear-cutting method, detrimentally affects martens (Soutiere 1979, Buskirk and Ruggiero 1994, Thompson and Harestad 1994, Hargis et al. 1999). Previous studies have shown that martens avoided open areas that lack overhead cover (Buskirk and Powell 1994) and selected mature forest types over regenerating clear-cuts within their home ranges (Payer 1999). Also, forest fragmentation and the associated increase in second-growth stands on the landscape are associated with alterations in habitat selection by martens and reduced survivorship and reproduction (Thompson and Harestad 1994, Bissonette et al. 1997, Chapin et al 1998). Therefore, forest management activities on the TNF were expected to affect population abundance of these carnivores (Sidle and Suring 1986).

Densities of martens have been linked to availability of prey, primarily small mammals (Thompson and Colgan 1987). Kartashov (1989) demonstrated that in sables (*M. zibellina*) the percent of breeding females varies greatly among years. Thompson and Colgan (1987) as well as Strickland and Douglas (1987) observed lower ovulation rates in *M. americana* during years of low prey availability accompanied with declines in population numbers. Similarly, other studies identified small rodents as the most common prey in diets of martens (Buskirk and MacDonald 1984, Douglas et al. 1983, Martin 1987, 1994, Thompson and Colgan 1990). Based on these observations, the TLMP conservation strategy assumed that in years of low prey abundance 25 and 5 resident female martens would inhabit large (≥ 16,200 ha) and medium (≥ 4,047 ha) OGRs, respectively. These assumptions and relationships were based on the best information available at the time including a review of the current literature and preliminary information from a field study in progress on Chichagof Island (Suring et al. 1993). Subsequent studies (Flynn and Schumacher 2001) on Chichagof Island found lower marten abundance in years of high prey availability than those assumed in the Forest Plan for years of low prey availability (R. W. Flynn, unpublished data). Therefore, the old-growth reserve system, as currently designed, likely will support fewer martens than assumed in the TLMP. If fewer, those populations may not be viable in the long-term unless additional conservation measures are implemented.

Furthermore, TLMP assumed that marten abundance and population dynamics were similar across the TNF. Because the composition and relative abundance of small mammal communities in Southeast Alaska differs substantially by island (Table 1), food availability for insular marten populations likely differs as well. For example, northern flying squirrels occur on the mainland and many islands in southern Southeast, but not on the larger islands of northern Southeast. Red-backed voles

Table 1. Mammalian prey items potentially available to American martens at 8 locations in Southeast Alaska (X = present; - = absent). Species distributions are based on MacDonald and Cook (1996). Actual species abundances will vary by location. Ungulate density index is based on deer pellet-group counts and presence of moose.

Location	Long-tailed voles	Tundra voles	Southern red-backed voles	Northern red-backed voles	Keen's mice	Northern flying squirrels	Red squirrels	Ungulate density index
Chichagof Is.	X	X	-	-	X	-	X	1.00
Etolin Is.	X	-	X	-	X	X	X	0.30
Kuiu Is.	X	-	-	-	X	-	X	0.32
Kupreanof Is.	X	-	-	-	X	-	X	0.56
Point Couverden	X	-	-	X	X	X	X	0.21
Prince of Wales Is.	X	-	-	-	X	X	-	0.69
Thomas Bay	X	-	X	-	X	X	X	0.59
Yakutat	X	X	-	X	X	-	X	0.41

(*Clethrionomys* spp.) occur on much of the mainland and only a few islands in central Southeast. Both species may be important food items. Long-tailed voles (*Microtus longicaudus*; a principal food for martens on Chichagof Island) occur on most islands and the entire mainland, but their abundance appears to vary substantially, especially temporally. For example, long-tailed voles occur on Mitkof Island, but only 4 records exist in the University of Alaska Museum collection (MacDonald and Cook 1996). On northeast Chichagof Island, vole numbers fluctuated between 0.0 and 11.1 captures/100 trap nights from 1991-1998 (Flynn and Ben–David, *in prep*). Studies of diets of martens conducted on Chichagof Island from 1991-1998 found that marten diets varied seasonally and annually, and were correlated with numbers of small rodents (Ben-David et al. 1997). On Chichagof Island martens fed on long-tailed voles year round during periods of high abundance, but switched to feed on salmon (*Oncorhynchus* spp.) during the fall in years when vole numbers were low (Ben-David et al. 1997, Flynn and Ben-David, *in prep*). Although alternative foods existed, marten abundance and productivity were related to an index of abundance of long-tailed voles. Nonetheless, on Chichagof Island the number of potential foods for martens was relatively limited and the number of potential mammalian prey restricted to 3 species including long-tailed voles, Keen's mice (*Peromyscus keeni*), and red squirrels (*Tamiasciurus hudsonicus*). We assumed that geographic areas with higher diversity of potential foods, such as other islands and mainland sites in the Alexander Archipelago, would support more numerous and stable marten populations.

In this study, we tested the assumption of the TLMP conservation strategy that OGRs on different island and mainland sites will support viable marten populations. Specifically, we estimated the density of martens on 8 island and mainland sites across Southeast Alaska and compared these densities with those listed in the TLMP conservation strategy. Next, we evaluated abundance and diets of martens in relation to the abundance of small mammals in these 8 locations. We expected that on islands with more diverse or stable rodent numbers, marten densities would be greater and populations would fluctuate less. Also, we predicted that in locations with high diversity of small mammals, martens would switch to alternative mammalian prey when vole numbers were low. In contrast, in areas with low diversity of small mammals, we predicted that martens would switch to feed on salmon when abundance of voles is low. Information from this study will be useful in evaluating the long-term viability of marten populations in the old-growth reserve system of the current Forest Plan.

STUDY AREAS

General

Southeast Alaska (Fig. 2) consists of rugged mountains, numerous islands, and conifer-dominated rain forest. Mountains rise from the sea to over 1,400 m. The maritime climate is cool, and moist throughout the year. In the Juneau area, the annual precipitation ranges from 135 cm at the airport to 236 cm at downtown. Heavy snow accumulations often occur during winter; higher elevations are snow-covered for 7 to 9 months of the year. The natural vegetation is dominated by temperate rain forest, one of the world's most limited ecosystems (Alaback 1988), interspersed with muskegs and alpine tundra. Because of the lack of frequent, large-scale, catastrophic natural disturbance, the rain forests of southeast Alaska are predominantly in an old-growth condition (Alaback and Juday 1989). Sitka spruce (*Picea sitchensis*) or western hemlock (*Tsuga heterophylla*) dominate the overstory of most plant associations on productive sites (Martin 1988, Alaback 1989, Samson et al. 1989). Poorly drained sites often contain mountain hemlock (*Tsuga mertensiana*), Alaska-yellow cedar (*Chamaecyparis nootkatensis*), or western red cedar (*Thuja plicata*). The understory, depending on site conditions, may be dominated by shrubs such as blueberry (*Vaccinium* sp.), rusty menziesia (*Menziesia ferruginea*), or devil's club (*Oplopanax horridum*). Bunchberry (*Cornus canadensis*), trailing raspberry (*Rubus pedatus*), and skunk cabbage (*Lysichitum americanum*) are common forbs.

In order to evaluate habitat composition, we used the timber type (TIMTYP) landcover map available from the U.S. Forest Service. Although developed for timber management purposes at a forest-wide scale (Caouette et al. 2000), this landcover map was the only digital database that encompassed all of our study areas. For this analysis, we used geographic information system (GIS) software to group land cover into 6 categories based on forest condition. Non-forest included alpine, shrub, muskeg, and estuary habitats. Clearcut habitat included those sites logged since 1970 because canopy closure by regenerating forest generally occurs at about 35 years after cutting (Alaback 1982). Scrub forest included unproductive, old-growth forest in volume class 3 (VC3). Volume class 4 (VC4) sites included all old-growth forest in VC4 only. Because we found little volume class 6 or 7 at most study areas or OGRs, we grouped all volume classes ≥ 5 as volume class 5^+ ($VC5^+$). Even-aged forest included stands originating from clearcuts prior to 1970, windthrow, or primary succession after deglaciation (i.e., Yakutat).

Specific Study Sites

We selected 8 geographic areas located across southeast Alaska for study based on geographic distribution, species assemblages and accessibility (Fig. 2). The selected areas represented distinct assemblages of potential marten prey species. Mammal species considered included Keen’s mice, long-tailed voles, northern red-backed voles (*Clethrionomys rutilus*), southern red-backed voles (*C. gapperi*), red squirrels, northern flying squirrels, shrews (*Sorex* sp.), and Sitka black-tailed deer (*Odocoileus hemionus sitkensis* (Table 1, Fig. 3). Moose (*Alces alces*) were present in a few areas, notably Thomas Bay and Yakutat. We based mammal distributions on MacDonald and Cook (1996), but had no prior data on

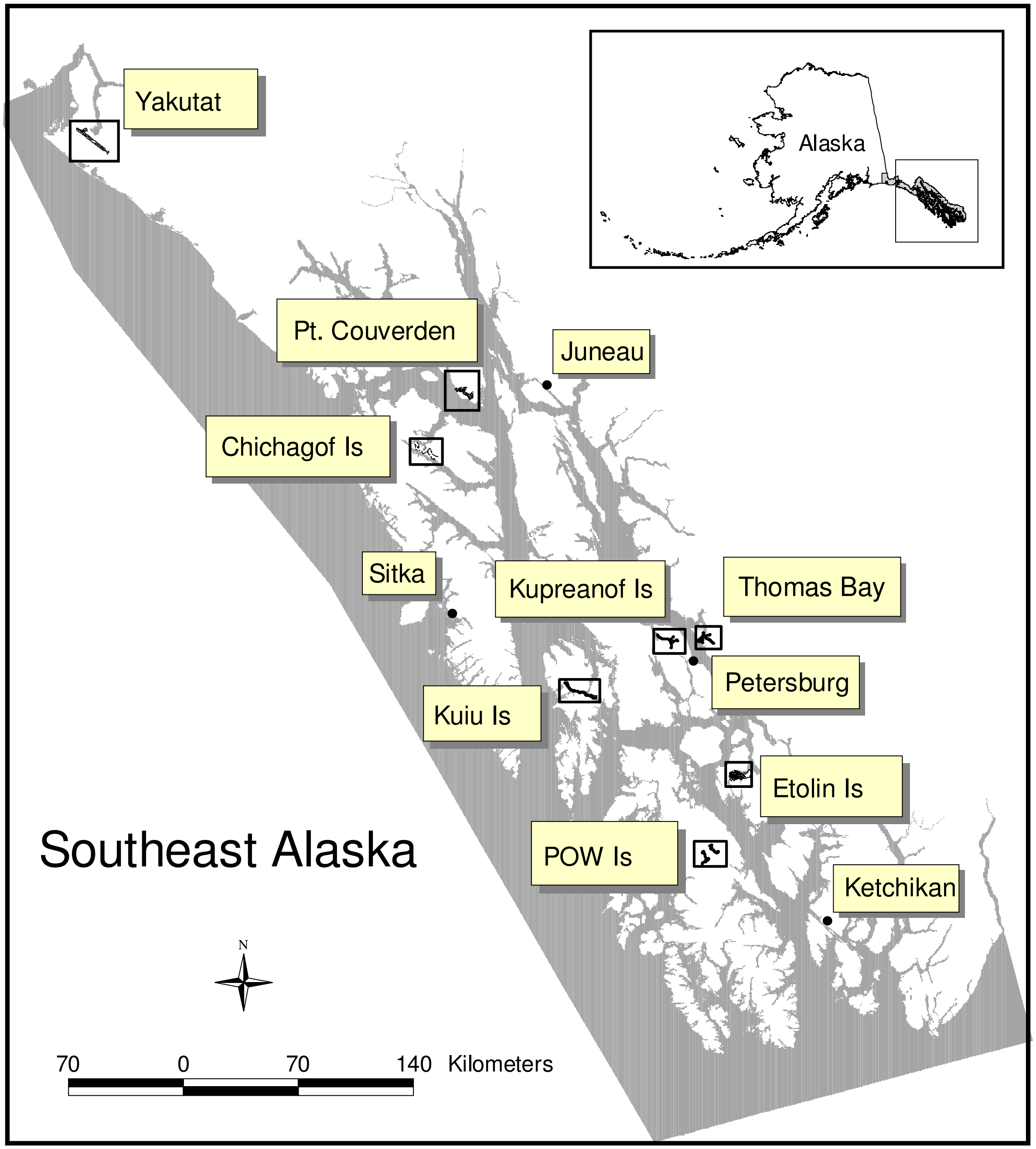

Figure 2. Map of study areas in Southeast Alaska.

species abundance. We expected species abundance to vary among study sites and over time. All sites had spawning Pacific salmon (*Oncorhynchus gorbuscha, O. keta*, and *O. kisutch*) available during the late summer and early fall. The resident avian fauna may include Steller's jay (*Cyanocitta stelleri*), blue grouse (*Dendragapus obscurus)*, spruce grouse (*Dendragapus canadensis*), and winter wren (*Troglodytes troglodytes*). Other songbirds such as dark-eyed junco (*Junco hyemalis*), robin (*Turdus migratorius)*, varied thrush (*Ixoreus naevius*), hermit thrush (*Catharus guttatus*),

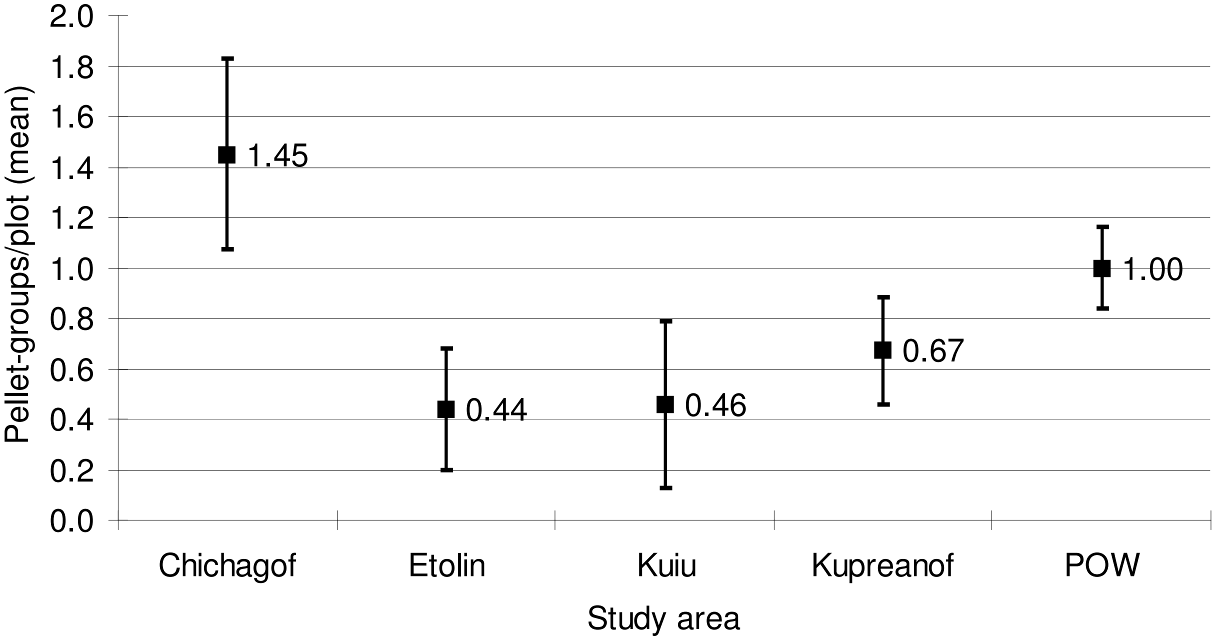

Figure 3. Relative density of black-tailed deer on study sites based on pellet-group transects (Kirchhoff 2003). Means and SEs based on all transects in an area since 1993. The number transects in an area varied from 3 on Kuiu Island to 5 on Chichagof and Prince of Wales Islands. The sample interval for a transect varied from 1 to 9 years. Pellet-group transect data were not available for Point Couverden, Thomas Bay, and Yakutat. At these sites, deer numbers were assumed similar to Etolin Island.

and Swainson's thrush (*Catharus ustulatus*), arrive for the breeding season in early May and depart during September. Although the distributions of grouse and ptarmigan (*Lagopus lagopus, L. leucurus, and L. mutus*) also vary across the region, we did not consider that these birds contributed significantly to marten diets. At each location, we selected specific study sites based on access and suitable habitat. In order to complete the marten surveys, a site had to be large enough to accommodate a 25-km trapline using logging roads or other access points. Ideally, the study sites contained old-growth reserves, other non-development land use designations (LUDs) with mostly suitable marten habitat, or adequate habitat to meet the minimum composition requirements of an old-growth reserve (at least 50% productive forest and 25% VC5$^+$).

Accessibility by vehicle during summer and fall and the availability of lodging facilities were important components in our selection of study areas. Unfortunately, most reserves designated in TLMP did not have adequate access for this project. Also, in order to minimize the effect of fur trapping on density estimates, we looked for study sites where little fur trapping had occurred in recent years. These sites tended to be either remote or under administrative regulations that limited access for marten trapping.

Chichagof Island.—Marten abundance on the Salt Lake Bay area on northeast Chichagof Island has been monitored since 1990 (Flynn and Schumacher 2000). To provide a link between our earlier studies (Ben-David et al. 1997) and this effort, we included the Salt Lake Bay study area as a survey site for this study (Fig. 2). About 80% of the Salt Lake Bay trapline crosses a designated OGR with the remainder in a timber management LUD. Within the effective trapping area (6,757 ha), the percentage of productive forest (59.3%) and the percentage of $VC5^+$ forest (31.8%) exceed the minimums. ADFG has a facility at Salt Lake Bay, and a vehicle was temporarily available for this project. Mammal species of interest on Chichagof Island include long-tailed voles, Keen's mice, red squirrels, and abundant deer. Although restricted to a few species, small mammals on Chichagof Island are some of the largest in the region. We found that long-tailed voles averaged 20 g more than red-backed voles. Although considered the same species now (MacDonald and Cook 1996), Keen's mice on Chichagof Island averaged 7.9 g more than those from all other places. Previously, the deer mice on Chichagof were described as a separate species (*Peromyscus sitkensis*) (Hall 1981) because of their larger size. Now, they are recognized as a subspecies (*P. k. sitkensis)* (MacDonald and Cook 1996) although additional analyses are needed (Lucid and Cook 2004). A larger food packet size may help compensate for situations with less numerous prey.

Based on deer pellet-group surveys (Fig. 2), the relative ungulate density index was rated as high. Marten and small mammal trapping occurred in fall (September to November) 2002 and 2003. Data encompassing our investigations from 1990 – 1998 (Ben-David et al. 1997, Flynn and Schumacher 2001) were also included when appropriate.

Etolin Island.—We selected an area on northern Etolin Island near Anita Bay for a survey site (Fig. 2). Because the designated medium OGR on north Etolin has no road access, we chose a nearby area with road access. Although nearly the entire trapline fell into a timber management LUD, the effective trapping area (7,263 ha) closely resembled the minimum habitat composition requirements of a reserve. The percentage of productive forest falls 9% short of the minimum standard, but the percentage of $VC5^+$ forest exceeds the minimums. A Forest Service facility with housing, vehicle, and fuel exists at Anita Bay. Mammal species of interest on Etolin Island included long-tailed voles, Keen's mice, red-backed voles, red squirrels, northern flying squirrels, deer, and wolves. Sealing records indicated little marten trapping on Etolin Island during recent years. Based on deer pellet-group surveys (Fig. 2), the relative ungulate density index was rated as low. Marten and small mammal trapping occurred in fall 2002.

Kuiu Island.—The selected trapline included 29 km of Forest Service roads (4607, 6402, 6434, and 46095) located east of Rowan Bay on northern Kuiu Island (Fig. 2). About 23.4 km (81%) of the trapline passed through non-development LUDs with about 15 km in a medium OGR. Another 8.5 km of the trapline crossed an area to be managed for remote recreation. Collectively, the 1.6-km buffered trapline included sufficient habitat to meet the minimum requirements of an OGR. Because parts of the trapline passed near the beach, the effective trapping area included a land area of 6,714 ha. Although open to trapping, no marten fur harvest had been reported from the area since 1986. A Forest Service facility with housing, vehicle, and fuel existed at Rowan Bay. Mammal species of interest on Kuiu Island included long-tailed voles, Keen's mice, red squirrels, deer, and wolves. Although present, deer numbers have been low for many years. Based on deer pellet-group surveys (Fig. 2), the relative ungulate density index was rated as low. Marten and small mammal trapping occurred in fall 2001 and 2002.

Kupreanof Island.—We selected an area on northern Kupreanof Island near Portage Bay for a survey site (Fig. 2). Although nearly the entire trapline falls into a timber management LUD, the effective trapping area (8,425 ha) met the minimum habitat composition requirements of a reserve. A Forest Service facility with housing, vehicle, and fuel existed at Portage Bay. Mammal species of interest on Kupreanof Island included long-tailed voles, Keen's mice, red squirrels, deer, moose, and wolves. Although similar in mammal composition to Kuiu Island, deer numbers on Kupreanof Island are higher. Based on deer pellet-group surveys (Fig. 2), the relative ungulate density was rated as low. Marten and small mammal trapping occurred in fall 2002 and 2003.

Point Couverden.—We added this mainland site, located 54 km west of Juneau, in 2003 (Fig. 2). The trapline included 39.4 km of logging road. Within the effective trapping area (8,128 ha), the percentage of productive forest (56.2%) and the percentage of VC5$^+$ forest (27.4%) exceeded the OGR minimums. The small mammal fauna included long-tailed voles, Keen's mice, northern red-backed voles, red squirrels, and northern flying squirrels. Sitka black-tailed deer, moose, and wolves were also present, but in low numbers. Because of low deer numbers, pellet-group surveys had not been done here. Thus, we rated the relative ungulate density index as low. Marten and small mammal trapping occurred in fall 2003.

Prince of Wales Island.—We chose the Honker-Divide area on north-central Prince of Wales Island (POW) as a study site (Fig. 2). This area includes the Honker Divide OGR (Fig. 1) and 2 Forest Service roads penetrate the reserve, including the Cutthroat Road (13.7 km) and the Honker Road (10.8 km). The Cutthroat Road provided access to the western portion of the reserve. On the east, the Honker Road enters the reserve, and then exits for 5 km into a scenic viewshed LUD. The effective live-trapping area based on a 1.6-km buffer along the trapline was 8,609 ha. Both of these roads had been closed to the general public by a locked gate. Thus, we expected little fur trapping along these roads. Habitat composition within a 1.6-km trapline buffer met the minimum requirements of an OGR. Mammal species of interest on Prince of Wales Island include long-tailed voles, Keen's mice, northern flying squirrels, deer, and wolves. Based on deer pellet-group surveys (Fig. 2), the relative ungulate density index was rated as medium. Marten and small mammal trapping occurred in fall 2001, 2002, and 2003.

Thomas Bay.—For a mainland site, we selected an area near Thomas Bay for a survey site (Fig. 2). The designated OGRs near Thomas Bay have no road access, so we chose an area with road access that closely resembles the minimum composition requirements of OGR. On Forest Service lands, most of the trapline crossed a scenic viewshed LUD. Part of the trapline crossed state lands. Within the effective trapping area (6,440 ha), the percentage of productive forest (42.6%) falls short of the standard (50%), but the percentage of VC5$^+$ forest (27.6%) exceeds the minimums. ADFG has a cabin at Thomas Bay and the Forest Service provided a vehicle. Potentially, Thomas Bay had the entire compliment of mammal species of interest including long-tailed voles, red-backed voles, Keen's mice, red squirrels, northern flying squirrels, deer, and wolves. Sealing records indicated occasional marten trapping along the shoreline of Thomas Bay, but no recent trapping along the road system. Because not considered an important deer area, adequate deer pellet-group surveys had not been completed to provide a reliable index. In calculating the ungulate index, we assumed that deer numbers were low and similar to nearby Etolin and Kupreanof Islands. We increased the index by 0.2 to account for the substantial moose population. Marten and small mammal trapping occurred in fall 2001 and 2002.

Yakutat.—We added this mainland site, located 340 km northwest of Juneau, in 2003 (Fig.2). The trapline was 30.0 km long. Within the effective trapping area (10,021 ha), the percentage of productive forest (68.2%) and the percentage of VC5$^+$ forest (57.1%) exceed the minimums. The small mammal fauna included long-tailed voles, Keen's mice, northern red-backed voles, red squirrels, and northern flying squirrels. Moose were the primary ungulate and wolves were also present. Deer numbers were believed to be low and no pellet-group data were available. Based on the presence of moose, the relative ungulate density index was rated as low. Marten and small mammal trapping occurred in fall 2003.

Habitat Evaluation

We evaluated whether the composition and spatial distributional patterns of habitats within our study areas were representative of habitats within nearby medium and large OGRs. Because most of the actual OGRs were inaccessible, we used our study areas as surrogates for OGRs. Thus, we wanted to establish whether the habitats within our study areas differed from the established OGRs.

We buffered each marten trapline by 1.6 km to delineate our study areas for the habitat composition analysis. All salt water was considered non-habitat and eliminated from the study areas. Although OGRs were not explicitly mapped in the GIS as a LUD, we used the LUD GIS coverage from TLMP to identify nearby Old-growth Management LUDs that best approximated the composition, size, and distance requirements of medium or large OGRs (U.S. Forest Service 1997). Where the nearest lands with an Old-growth LUD were much smaller than a study area, we grouped up to 3 of the nearest old growth LUD areas together and considered the combined area as an OGR for the analysis. Five of our study areas overlapped with or were adjacent to OGRs. At 2 sites, Thomas Bay and Point Couverden, OGRs were <2.5 km from our study areas and at Yakutat 1 of the 3 OGRs used was 11.5 km from the study area. We observed no significant barriers to marten dispersal between any pairing of study areas and potential OGRs.

We calculated habitat composition of trapped areas and OGRs and compared 95% confidence intervals around means for proportions of each habitat (Fig. 4). Habitat composition of all study areas and OGRs, except those on Etolin Island, met the minimum forest composition requirements established in TLMP. The Etolin Island study area had 9.4% too little forest in volume classes ≥4 and 3.6 % too little forest in VC5$^+$, whereas the OGR had 1.1% too little forest in volume classes ≥4, but sufficient VC5$^+$ forest. Proportions of lands in each habitat category varied little between study areas and OGRs. The only habitat for which 95% confidence limits did not overlap was clearcut. Study areas had significantly more clearcut habitat than OGRs. Thus, we concluded that the habitat composition of study areas were adequately similar to

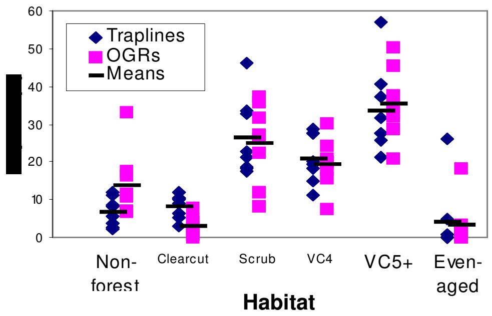

Figure 4. Habitat composition of 8 marten study areas and nearby old growth reserves on the Tongass National Forest, Southeast Alaska, 2001-2003. Habitat classes were derived from the Tongass TIMTYP GIS databases.

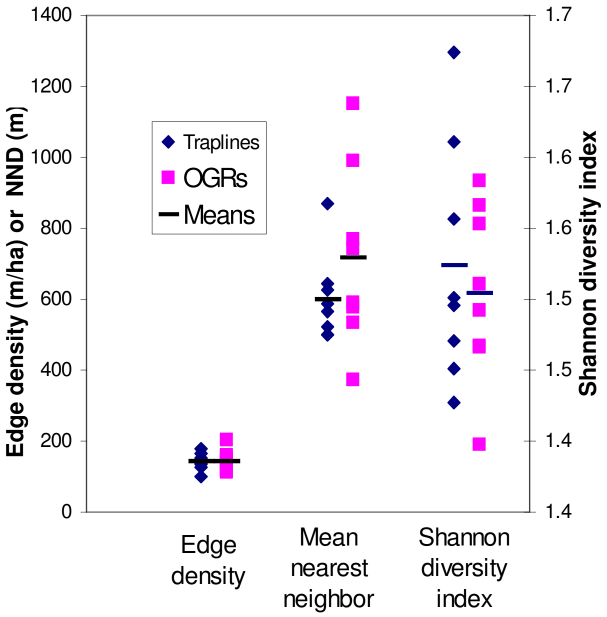

Figure 5. Values of 3 landscape metrics for 8 marten study areas and nearby old growth reserves in Southeast Alaska, 2001-2003.

nearby OGRs

In addition to habitat composition, we compared landscape spatial metrics of the study areas and nearby OGRs. For this analysis, we computed 21 spatial statistics using FRAGSTATS (McGarigal and Marks 1995) as implemented with the Patch Analyst extension for ArcView (Elkie et al. 1999). Similar to the habitat composition evaluation, we compared 95% confidence intervals around means for selected spatial variables. If confidence intervals did not overlap, we considered differences significant.

We selected relevant spatial variables by examining correlations among spatial measures and correlations between measures and mean marten density. Also information on habitat selection provided by Snyder and Bissonette (1987), Chapin et al. (1998), and Potvin et al. (1999) was considered. Of the spatial metrics, edge density (ED), Shannon diversity index (SDI), and mean nearest-neighbor distance (MNN) were poorly correlated among themselves and correlated with mean marten capture rate. ED is the amount of edge relative to the landscape. SDI, a measure of patch diversity, reflects the number of habitat types and how evenly the study area is distributed among habitat types. MNN, a measure of patch isolation, is the mean edge-to-edge distance between patches of similar habitat. Mean values and ranges for these variables at study areas and OGRs were similar (Fig. 5), and 95% confidence intervals overlapped.

The study areas and adjacent OGRs did differ in road density though. The study areas averaged 3.36 m/ha (SD = 0.52, *n* = 8) of logging road. By design, the road density in OGRs was low (U.S. Forest Service 1997).

METHODS

Marten Abundance and Density

Marten captures.—At each site, a 25-km trapline was established using logging roads or other access points. Along each trapline, trap stations were spaced at about 0.5-km intervals. At each station, a single, wire live trap (Model 203, Tomahawk Live Trap Co., Tomahawk, WI) was covered with a piece of plastic tarp then placed under a log or stump located adjacent (15-40 m) to the logging road or other access point. Traps were set, baited with sardines, or jam, scented with commercial marten lure (Flynn and Schumacher 1996), and checked daily for 5-6 consecutive nights.

For immobilization, captured martens were confined to 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). All captured martens were sexed, then eartagged (Size 1, Style 1005, National Band and Tag Co., Newport, KY) for individual identification. Animals were left in the trap until recuperated, then released at the site of capture. Independent Animal Care and Use Committees at the University of Wyoming and the Alaska Department of Fish and Game (ACUC 03-0011) approved all methods of animal handling used in this study.

Marten density.—For each area we first calculated capture rates by dividing the number of captures by total number of trap nights (TN). We then estimated marten abundance on each study site based on the number of unique individuals captured during the trapping session. Previous mark-recapture studies on Chichagof Island found a strong relationship between the number of unique marten captures and the estimated population size (Flynn and Schumacher 2001). During these mark-recapture surveys, the mean capture probability was 0.64 (n = 16 trapping sessions, SE = 0.05) (ADFG, R. W. Flynn, unpublished data). For this study, we assumed that the mean probability of capture at any time during the survey was similar to that of Chichagof Island. In addition, Flynn and Schumacher (1993) found that female martens on Chichagof Island have an average home range size (95% minimum convex polygon) of 5.3 km^2 (n = 13, SE = 0.7) and males to have a mean home range size of 7.8 km^2 (n = 28, SE = 1.1). We estimated the effective trapping area by assuming that all martens with a home range intersecting a trapline had a capture probability equal to the average measured on Chichagof Island (Flynn and Schumacher, *in prep.*). We estimated the effective trapping area by buffering the trapline by the mean radius of home ranges. Because of different home range sizes, we computed the buffer distances separately for males ($\bar{x}$ = 1.51 km, SE = 0.1) and females ($\bar{x}$ = 1.25 km, SE = 0.1). We separately estimated variance of the effectively trapped areas for males and females at each study site based on means of 300 bootstrap samples of actual home range diameters from Chichagof Island.

We estimated male and female marten density separately by using:

$$\hat{d} = \frac{C}{(p * A)},$$

where:

d = density of male or female martens per hectare,

C = number of unique males or females captured,

p = probability of capture (0.64),

A = the mean effectively trapped area for either sex,

with variance estimated by:

$$\text{var}(\hat{d}) \cong (\hat{d})^2[\frac{1}{C} + \frac{\text{var}(A)}{A^2} + \frac{\text{var}(p)}{(p)^2}]$$

This variance estimation included the combined variances of the capture probability and home range size (G. Pendleton, ADFG, personal communication). We estimated the number of male and female martens that would likely inhabit a 16,200 ha OGR associated with a given study area by multiplying the estimated density in the study area by 16,200 ha. We scaled the variance of the estimated density of martens per hectare to the magnitude of a large OGR by multiplying the variance by 16,200 ha and used standard methods to calculate confidence intervals.

Marten sex and age ratios and body condition.—In order to gather additional information on population status, we sexed, aged, weighed and measured each animal. We used deviations from body mass predicted by linear regressions between body mass and total body length as a measure of body condition (BCI) for captured martens. These relationships were developed using all martens live-captured in Southeast Alaska since 1991 (Flynn and

Ben-David, *in prep.*). First, the mean total length was computed for each animal with multiple captures. We assumed that individuals had reached their full length when first captured, and any subsequent differences in body length were attributed to measurement error. Because of strong sexual dimorphism, we computed regression equations for males and females separately (males: $y = 2.544x - 455.8$, $r^2 = 0.139$; females: $y = 1.9929x - 347.3$, $r^2 = 0.198$, where y = body mass (g) and x = total body length (mm). We used the standardized residuals from the regressions as our BCI. We pulled 2 first premolar teeth for age determination by cementum analysis (Matson's Laboratory, Milltown, MT). Age ratios were expressed as juveniles: adult and juveniles: adult female. Martens aged older than 1 year were considered adults. For all the population parameters, we compared means and 95% CIs among study areas and years.

Effect of fur trapping.—We examined the reported marten catch to gain insight into whether recent fur trapping had likely influenced marten abundance. To minimize the potential effect of fur trapping on our estimates of marten density, we selected study areas that had experienced little recent marten trapping. We gauged trapping activity using ADFG fur sealing records. Since 1984 trappers have been required to submit marten pelts harvested in all game management units (GMU) in Southeast Alaska for sealing by a Department designated sealer. We summarized harvest in two ways. First we calculated mean and peak harvest over a 12-year period for landscapes surrounding each study area. Then we summarized harvest from 1999-2002 for only the immediate vicinity of our study areas where animals residing on the study area were likely to be trapped. Also, trapping records provided insight on historic population trends in the larger area.

Landscape Habitat Analysis and Marten Abundance

To examine whether habitat features at our different study sites affected our estimation of density, we attempted to correlate landscape habitat features with marten density. Although we assumed the study areas met the minimum habitat composition requirements for an OGR, we examined correlations among the amount of productive old-growth forest habitat (VC4, $VC4^+$, and $VC5^+$) and marten density. Because the study areas were selected based on similar habitat composition, we did not expect marten density to be correlated with habitat composition.

As previously discussed, we used the Patch Analyst extension for ArcView (Elkie et al. 1999) to produce 21 metrics of landscape pattern for each study area (McGarigal and 1995). In order to select variables to compare with marten density, we examined correlations among these spatial measures. We then chose variables that were poorly correlated with each other and thought related to marten habitat ecology (Hargis and Bissonette 1997, Chapin et al. 1998, Potvin et al 2000). We explored the relationships among 4 of the spatial statistics and marten density using multiple regression. For this analysis, we weighted each observation by the number of repeated observations per study area using weighted least squares. In the regression model, we attempted to predict mean marten density using number of patches (NP), edge density (ED), SDI, and MNN as explanatory variables.

Small Mammal Abundance

The relative abundance of small mammals, excluding squirrels, was estimated using a snap-trap index similar to Calhoun (1948). We did not collect information on squirrel or berry abundance because of time and effort limitations. We established transects in at least 2 old-growth forest stands at each study site: a productive western hemlock stand and a mixed conifer/blueberry stand (Marten 1989). At some sites, 2 transects were placed in each habitat. Each transect consisted of 25 trap stations placed at 15-m intervals. During the early fall, we placed 2 Museum Special snap traps at each station, baited them with a mixture of peanut butter and rolled oats, and set for 3 consecutive nights (450 trap nights). Traps were checked once daily. The number of animals captured by species was recorded and expressed as the number of captures per 100 trap nights. We calculated means and CIs for each habitat and year by study area. All specimens were weighed and sent to the University of Alaska Museum, Fairbanks.

Similar to the marten density analysis, we explored the relationships among 4 of the spatial statistics and small mammal abundance using multiple regression. For this analysis, we weighted each observation by the number of repeated observations per study area using weighted least squares. In the regression model, we attempted to predict the abundance of each small mammal species using NP, ED, SDI, and MNN as explanatory variables.

Marten Diets

Diet composition.—We determined autumn marten diets on each study site using stable isotope analysis (SI; Ben-David et al. 1997, Szepanski et al. 1999). Applying SI analysis to tissues, such as blood, allowed repeated sampling of known individuals (Ben-David et al. 1997, 2001), enabling us to investigate individual diets and the factors underlying feeding habits of individuals among study areas and years. In this analysis, comparisons of δ^{13}C and δ^{15}N of potential prey and predator provided information on the dietary composition of the predator during the proceeding 3-4 weeks (Ben-David et al. 1997, 1998a).

To determine the isotopic signatures of marten prey, muscle tissue samples were collected from all small mammals captured in this study (see section on Small Mammal Abundance). Data for other potential food items such as squirrels, berries, and salmon were adopted from our earlier studies on Chichagof Island (Ben-David et al. 1997). To determine the isotopic signatures of martens, a 3.0 cc blood sample was drawn from the jugular vein of all captured martens. The blood was allowed to clot, the serum separated, and the remaining material was frozen for storage. All samples from captured martens and small mammals were sent to the Department of Zoology and Physiology at the University of Wyoming for SI analysis.

Tissues (clotted blood cells and muscle samples) were kept frozen until preparation for determination of stable isotope ratios. Although lipid contents may deplete values of δ^{13}C of tissues (DeNiro and Epstein 1978, Kelly 2000), samples were not defatted because clotted blood cells, hair, and vegetation contain low amounts of lipids and no difference was detected in δ^{13}C in salmon fat and defatted muscle tissues (Ben-David 1996). Samples of blood and muscle were dried at 60° - 70° C for 48 h and then ground to fine powder using a dry tissue grinder (Glenn Mills Inc., Clifton, NG). Subsequently, all samples were weighed into a miniature tin cup (4 by 6mm) for combustion. We analyzed sub-samples with a Carlo-Erba series 2 C/N analyzer attached to a VG Optima mass spectrometer to obtain the stable isotope ratios as well as values of percent C and N (Ben-David et al. 1998a, 1998b). Each sample was analyzed in duplicate and results accepted only if the variance between the duplicates did not exceed that of the peptone standard (δ^{13}Cstd

= -15.8, δ^{15}Nstd = 7.0, CV = 0.1). Samples were analyzed at the mass-spectrometry facility at the University of Wyoming.

We used a K nearest-neighbor randomization test (Rosing et al.1998) to determine whether isotopic signatures of small mammals differed between the study areas and through time. To establish whether martens switched to alternative prey when vole numbers were low, we used the program IsoSource (Phillips and Gregg 2003) to calculate an index of the proportion of each food item in the diet of martens. For each study area, we used the end-members from that site except for those islands and mainland sites for which we had no samples of prey. For those locations and periods, we used the values of the nearest location and the closest time period. Values for salmon, berries, and squirrels were only available for Chichagof Island from 1992-1994. We used diet-tissue enrichment of 2% for carbon when mammalian prey, avian prey, and berries were consumed, and 1% when salmon or invertebrates were consumed, based on results from feeding experiments in captivity on mink (*Mustela vison*) and black bears (Ben-David 1996, Ben-David and Schell 2001, Hilderbrand et al. 1996). Also, based on the captive experiments we used fractionation values of 3% for nitrogen (Ben-David 1996, Hilderbrand et al. 1996).

To explore the relation between abundance of voles and diet of martens, we used non-linear curve estimation (SPSS 11.5 for Windows) with number of vole captures per 100 trap-nights as the independent variable and δ^{15}N as the dependent one. We repeated the analysis with number of vole captures per 100 trap-nights as the independent variable and percent salmon in the diet derived from the output of IsoSource as the dependent one.

We used multiple regression analysis to investigate which measures of food abundance might best predict abundance of martens. We used marten density as the dependent variable and measures of ungulate density and estimated biomass of 3 small mammal species as the independent variables. For this analysis, we weighted each observation by the number of repeated observations per study area using weighted least squares. In this regression model, food variables were added in a step-wise manner ($P < 0.1$).

We estimated relative abundance of ungulates based on annual deer pellet group survey data (Kirchhoff 2003) gathered near our study areas (Fig. 3). Mean deer-pellet counts were scaled to range from 0-1. No recent deer surveys had been completed at Point Couverden, Thomas Bay, and Yakutat because of believed low deer numbers. A lack of field sign indicated that deer were scarce at Point Couverden and Yakutat, but populations appeared higher at Thomas Bay. For this analysis, we assumed that deer numbers at Point Couverden and Yakutat were similar to Kuiu Island. For Thomas Bay, we assumed that deer numbers were mid-way between nearby Kupreanof and Etolin Islands. For study areas where significant moose or elk populations were present, we adjusted the ungulate index slightly upward (+0.1 for Kupreanof and +0.2 for Thomas Bay and Yakutat). We estimated relative biomass of long-tailed and red-backed voles and Keen's mice on each study area each year by multiplying the capture rate for each species by the mean body weight of each species (i.e., g per 100 TNs). Because we found that Keen's mice on Chichagof Island averaged 7.9g ($t = 15.6$, $P < 0.001$) more than those from the other study sites, we used the measured value for that location (27.1g).

Finally, we tried to predict marten density using a combination of food and habitat variables. In this regression model, food and habitat variables were added stepwise ($P <$

0.1), and each observation was weighted by the number of repeated observations per study area using weighted least squares. The predictive ability of this combined model was compared with the previous food only model.

RESULTS

Marten Abundance and Density

Marten captures.—From September 2001 to December 2003, we captured 85 individual martens (50 M, 35 F) from 1–3 times in the 8 study areas. Usually, trapping effort in each area ranged from 250-300 trap nights (TN) per year. However, we had as few as 178 TN at Chichagof Island in 2003 and as many as 338 TN at POW in 2001. Reduced trapping effort in some areas resulted from logistical difficulties including logs temporarily blocking roads, vehicle problems, and bad weather delaying air travel.

The highest numbers of individuals were captured on Chichagof Island (22) and at Thomas Bay (19, Table 2). Even with only 178 TN of effort, we caught the third highest number of martens (10) on Chichagof Island in 2003. The actual number of female martens captured was low at most sites. We captured only 1 female on Etolin and Kuiu islands in 2002. The highest numbers of female martens caught were 7 on Chichagof Island in 2002 and 4 at Point Couverden.

Table 2. Age and gender classifications of marten live-trapping surveys at 8 study areas in Southeast Alaska during fall 2001-2003. Juvenile (Juv.) martens = age class 0. Adult martens are ≥ 1 year old.

		Males		Females			Captures/100TN		
Study area	Year	Juv[a]	Adult[a]	Juv[a]	Adult[a]	TN	Males	Females	Juv per adult female
Chichagof Is.	2002	5	2	4	3	239	2.9	2.9	3.
	2003	3	1	2	4	178	2.2	3.4	1.3
Etolin Is.	2002	0	0	0	1	223	0	0.4	0
Kuiu Is.	2001	1	0	0	2	279	0.4	0.7	0.5
	2002	0	1	0	1	298	0.3	0.3	0
Kupreanof Is.	2002	0	4	1	0	272	1.5	0.4	--
	2003	4	1	1	0	249	2.0	0.4	--
Point Couverden	2003	2	2	1	3	291	1.4	1.4	1.0
Prince of Wales Is.	2001	2	1	0	2	338	0.9	0.6	1.0
	2002	2	2	1	0	225	1.8	0.4	--
	2003	2	1	1	1	212	1.4	0.9	3.0
Thomas Bay	2001	3	3	0	3	281	2.1	1.1	1.0
	2002	6	3	1	2	266	3.4	1.1	3.5
Yakutat	2003	0	2	2	1	294	0.7	1.0	2.0

[a] Ages determined using counts of cementum annuli.

Capture rates varied widely among areas (Table 2). The highest capture rates were on Chichagof Island and at Thomas Bay, and the lowest capture rates were at Kuiu and

Etolin islands. The highest capture rate on Chichagof Island (5.8/100TN) was over 14 times greater than the lowest capture rate on Etolin Island (0.4/100TN). Capture rates for female martens varied from 3.4 captures/100TN on Chichagof Island in 2003 to 0.3 captures/100TN on Kuiu Island in the same year (Table 2). Capture rates for areas visited in consecutive years were similar at Chichagof Island and POW between 2002 and 2003. Differences in capture rates between years at other areas mostly resulted from capturing one more or fewer martens than during the previous year. Thomas Bay was an exception where with 15 TN less effort we caught 3 more martens in 2002 than in 2001. We visited 5 of the study areas in 2 consecutive years (POW 3 consecutive years), but recaptured few previously marked martens (Table 2). In these 5 areas, 69 martens were marked but we recaptured only 5 (7.2%). We had no indication that any of these individuals were harvested prior to subsequent surveys.

Marten density.—We estimated densities of female and male martens on our study areas during each trapping session (Table 3). Based on these densities, we calculated the likely number of females and males present in a large (16,200 ha) OGR in the same area (Table 3). The point estimates for numbers of females inhabiting a large OGR were less than the 25 assumed in TLMP at all study areas except Chichagof Island. Point estimates for Point Couverden and Thomas Bay were 19 and 15 females, respectively. Estimates for the remaining 5 study areas ranged from 4–10 females in a large OGR. In all cases, variance associated with these estimates was large, resulting in relatively broad confidence limits. Still, 80% confidence limits at only 3 of 8 study areas included 25. Patterns in abundance of male martens were similar to females with the highest estimates at Chichagof Island, Thomas Bay, and Point Couverden. However, the point estimate for males on Kupreanof Island was also similar to Chichagof Island and Point Couverden.

Marten sex and age ratios and body condition.—In most areas we caught similar numbers of males and females, but at Thomas Bay and Kupreanof Island we caught mostly males (Table 2). The capture rate for females on Chichagof Island (2.9 and 3.4/100TN) was more than double that of other sites. The number of juveniles captured per adult female varied among areas, with no consistent pattern. For example, we found similar ratios of juveniles to adult females at Chichagof Island and Thomas Bay where martens were relatively abundant and at POW where martens were relatively scarce. We caught juvenile martens, but no adult females on Kupreanof Island in 2002 and 2003 and on POW in 2002.

Mean body condition index varied greatly among areas and years ranging from -0.31 in Thomas Bay in 2002 to 1.50 on Kuiu in 2002 (Table 4). When grouped by study area by year, marten BCI did not differ by sex (t = 0.78, df = 12, P = 0.45) and averaged 0.53 (n = 13, SD = 0.86) for males and 0.24 (n = 14, SD = 0.75) for females. We found no significant relationship between BCI and marten density (r = -0.34, P = 0.120). Similarly, we found no relationships among marten BCI and rodent biomass (long-tailed voles r = - 0.181; P > 0.268; Keen's mice r = 0.062, P = 0.416; and red-backed voles r = 0.154, P = 0.120).

Table 3. Estimated densities and numbers of female and male martens in 16,200 ha old growth reserves (OGR) on 8 study sites in the Tongass National Forest, Southeast Alaska, 2001-03.

Study area	Year	Number captured	Marten density per 1000 ha (var)	Martens in 16,200 ha OGR	Confidence limits (80%)	
					Lower	Upper
Females						
Chichagof Is.	2002	7	1.7 (0.67)	31	14	48
	2003	6	1.6 (0.56)	27	11	42
Etolin Is.	2002	1	0.3 (0.09)	5	0	11
Kuiu Is.	2001	2	0.6 (0.20)	10	1	19
	2002	1	0.3 (0.09)	5	0	11
Kupreanof Is.	2002	1	0.3 (0.08)	5	0	10
	2003	1	0.3 (0.08)	5	0	10
Point Couverden	2003	4	1.2 (0.39)	19	6	32
Prince of Wales Is.	2001	2	0.5 (0.14)	8	1	16
	2002	1	0.3 (0.07)	4	0	9
	2003	2	0.5 (0.14)	8	1	16
Thomas Bay	2001	3	0.9 (0.30)	15	3	26
	2002	3	0.9 (0.30)	15	3	26
Yakutat	2003	3	0.6 (0.15)	10	2	18
Males						
Chichagof Is.	2002	7	1.7 (0.53)	28	13	43
	2003	4	1.0 (0.28)	16	5	27
Etolin Is.	2002	0	--	--	--	--
Kuiu Is.	2001	1	0.2 (0.06)	4	0	9
	2002	1	0.2 (0.06)	4	0	9
Kupreanof Is.	2002	4	0.9 (0.26)	15	5	26
	2003	5	1.2 (0.34)	19	7	31
Point Couverden	2003	4	1.0 (0.29)	16	5	26
Prince of Wales Is.	2001	3	0.6 (0.14)	10	2	18
	2002	4	0.8 (0.20)	13	4	23
	2003	3	0.6 (0.14)	10	2	18
Thomas Bay	2001	6	1.6 (0.49)	25	10	40
	2002	9	2.3 (0.81)	38	19	56
Yakutat	2003	2	0.3 (0.06)	6	0	11

Table 4. Body condition indices (BCI; mean and SE) for marten captured during surveys 2001-2003 at 8 study areas, Southeast Alaska.

Location	Year	Males			Females			All		
		n	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE
Chichagof Is.	2002	6	-0.33	0.37	6	-0.14	0.40	12	-0.24	0.26
	2003	5	0.57	0.13	6	1.03	0.55	11	0.82	0.30
Etolin Is.	2002	0	-	-	1	0.01	-	1	0.01	-
Kuiu Is.	2001	1	0.45	-	2	0.4	0.3	3	0.59	1.17
	2002	1	2.63	-	1	0.37	-	2	1.50	1.13
Kupreanof Is.	2002	4	1.43	0.24	1	-0.45	-	5	1.06	0.42
	2003	6	-0.29	0.41	1	2.11	-	7	0.05	0.49
Point Couverden	2003	4	1.15	0.21	4	-0.03	0.39	8	0.56	0.30
Prince of Wales Is.	2001	3	0.43	0.52	1	-0.49	-	4	0.20	0.44
	2002	4	-0.24	0.31	1	0.25		5	-0.14	0.26
	2003	2	0.84	0.69	2	-0.60	0.68	4	0.12	0.57
Thomas Bay	2001	6	-0.34	0.34	3	-0.27	0.46	9	-0.31	0.26
	2002	9	-0.01	0.32	3	-0.08	0.21	12	-0.03	0.24
Yakutat	2003	2	0.60	0.09	3	1.03	0.7	5	0.86	0.17

Fur trapping.—Populations of martens surrounding all study areas experienced trapper harvest between 1991 and 2002 (Table 5). Mean annual harvest ranged from 224 martens/year on north central POW and 165 martens/year on Chichagof Island to 3 martens/year on northern Kuiu Island. Marten harvest was reported in all 12 years at POW and Chichagof Island and for 11 of 12 years at Yakutat and Kupreanof Island. However, most harvest occurred away from our study areas. In all but 2 cases, <10 martens were harvested in the immediate vicinity of study areas during winters preceding our surveys. Fur trappers caught 16 marked martens in 3 study areas. All but 1 of these martens were trapped after our final visit to an area, so fur trapping concurrent with our study had little influence on recaptures among years. A trapper caught 8 marked martens from the Thomas Bay road system during December 2002. We had captured 7 of those 8 martens during our October 2002 survey. A trapper caught 6 marked martens from the Kupreanof Island study area road system in January 2003. Of those 6 martens, we had captured 4 during our November 2002 survey, but not 2 other martens marked during 2001. The single marked marten harvested on POW was trapped away from the study area, about 22 km south of its original capture site.

Table 5. Trapper harvest of martens around 8 study areas in Southeast Alaska. Regional harvest indicates harvest for the population of which the study area was a part. Harvest in the vicinity of a study area represents harvest where martens residing on the study area were likely to be caught. Harvest data are from Alaska Department of Fish and Game fur sealing records.

	Regional marten harvest				Marten harvest in vicinity of study areas			
Study areas	Mean	Years with reported harvest	Peak harvest					
	1991-2002		No.	Year	1999	2000	2001	2002
Chichagof Is.	165	12	362	1996	0	0	1	3
Etolin Is.	11	6	55	1996	0	4	9	1
Kuiu Is.	3	2	17	2000	0	17	0	0
Kupreanof Is.	22	11	51	1999	19	24	0	0
Point Couverden	16	7	92	1998	0	18	0	0
Prince of Wales	224	12	377	2000	1	0	3	0
Thomas Bay	19	8	69	1998	30	0	3	25
Yakutat	68	11	211	1994	0	42	11	21[a]

[a] Residents of Yakutat indicated that 50 – 60 martens were actually trapped during the 2002-03 season.

Habitat Analysis and Marten Density

As expected, we found no significant correlations among marten density and variables representing the composition of forested habitats ($P > 0.21$). Of the spatial metrics, NP and SDI best predicted marten density ($r^2 = 0.58$, df = 11, $P = 0.003$) according to the model: $y = 3.21 - 0.007x_1 + 7.909x_2$, where x_1 = NP and x_2 = SDI. Although also correlated with marten density, MNN didn't enter into the regression model ($P < 0.1$) because of its correlation with NP ($r = -0.4273$, $P = 0.07$). Thus, landscapes with higher marten densities had fewer patches and a more even distribution of habitat patch types.

Small Mammal Abundance

Catch rates.—We sampled populations of small mammals in all study areas (Table 6). We caught voles, long-tailed or red-backed, at all sites except Kupreanof Island. Although long-tailed voles have been reported from all study areas (MacDonald and Cook 1996), we found them moderately abundant only on Chichagof Island, especially in 2002. By 2003, the catch rate declined there by about 60% (Table 7). Long-tailed voles were quite scarce in all other areas with only 1 captured on POW in 526 TN, 1 captured on Kuiu Island, and only 2 captured at Yakutat. Although long-tailed voles have been documented on the mainland near Point Couverden and on Kupreanof Island, we did not catch any there. Red-backed voles were abundant at all 3 mainland sites and Etolin Island, but they were not captured on the other islands.

Keen’s mice were very scarce on the mainland. We caught only 1 Keen’s mouse at Yakutat, few at Thomas Bay (0.3 and 1.0 captures/100TN), and none at Point Couverden. On the islands, catch rates of

Table 6. Mean capture rates for mice and voles in old-growth forest at all study areas in Southeast Alaska, fall 2001-2003. For each transect at each location, 2 Museum Special snap traps were set at 25 stations evenly spaced along a 360 m-long line and checked for 3 consecutive nights (150 trap nights). Captures are expressed as number per 100 trap nights.

Location	Year	*n*	Keen's mice		Long-tailed voles		Red-backed voles	
			$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Chichagof Island	2002	2	4.7	0.0	9.3	0.6	-	-
	2003	3	3.3	1.0	3.8	1.2	-	-
Etolin Island	2002	2	3.7	3.6	0.0		3.4	3.4
Kuiu Island	2001	2	4.7	0.7	0.4	0.3	-	-
	2002	2	7.7	2.3	0.0		-	-
Kupreanof Island	2002	2	4.7	4.6	0.0		-	-
	2003	3	3.5	1.0	0.0		-	-
Point Couverden	2003	4	0.2	0.2	0.0		16.9	2.9
Prince of Wales Island	2001	2	6.7	2.7	0.0		-	-
	2002	2	3.7	0.3	0.0		-	-
	2003	4	7.0	1.7	0.2	0.2	-	-
Thomas Bay	2001	2	0.4	0.3	0.4	0.3	4.4	2.3
	2002	2	1.0	0.3	0.0		6.7	1.4
Yakutat	2003	2	0.0		0.7	0.7	12.7	2.0

Keen’s mice ranged from 2.3 to 7.7 captures/100 TN. Compared to 2002, capture rates for mice on the islands were 30% and 25% lower on Chichagof Island and Kupreanof Island, respectively, but up by about 33% on POW.

Body mass.—The Keen's mice on Chichagof Island ($\bar{x}$ = 27.1 g, SE = 0.68) were significantly ($t = 15.6$, $P < 0.001$) greater in body mass compared with the other study sites ($\bar{x}$ = 19.2 g, SE = 0.18). Northern red-backed voles ($\bar{x}$ = 22.4 g, SE = 0.61) were slightly larger ($t = 2.3$, $P = 0.02$) than Southern red-backed voles ($\bar{x}$ = 21.0, SE = 0.30). Long-tailed voles ($\bar{x}$ = 40.7 g, SE = 0.93) were significantly ($t = 22.1$, $P < 0.001$) larger than red-backed voles ($\bar{x}$ = 21.4 g, SE = 0.29).

Habitat relationships.—We found no differences in mean rodent catch rates by habitat ($t = -0.049$, df = 31, $P = 0.31$). The mean catch rate for large/medium old-growth forest did not differ from intermediate-sized for any species. Mean catch rates did not differ by habitat for Keen’s mice ($t = -0.042$, df = 13, $P = 0.484$); long-tailed voles ($t = -0.082$, df = 13, $P = 0.214$), or red-backed voles ($t = -0.62$, df = 3, $P = 0.288$). We found no correlation between mean capture rate of long-tailed voles and Keen’s mice ($r = 0.064$, $P = 0.827$).

In a regression model, the catch rate of long-tailed voles was best predicted by the landscape variable MNN: $y = -410 + 0.749x_1$ (1), ($r^2 = 0.71$, df = 13, $P < 0.001$). In contrast, the biomass of Keen's mice was best predicted by the multiple regression model: $y = -44.82 + 1.0x_1 + 0.203x_2 - 198.0x_3$ (2), where x_1 = ED, x_2 = MNN, and x_3 = SDI ($r^2 = 0.58$, df = 11, $P = 0.003$). Red-backed vole abundance was best predicted by the multiple regression model: $y = 1056 - 4.6280x_1 - 0.483x_2$ (3), where x_1 = ED, ($P = 0.001$) and x_2 = MNN ($P = 0.038$) ($r^2 = 0.606$, df = 13, $P = 0.038$). Thus, long-tailed voles were more numerous in a landscape with more diverse and evenly sized habitat patches. Red-backed voles were also most numerous in landscapes with less fragmentation and evenly spaced habitat patches. The biomass of Keen's mice was greater in more fragmented landscapes.

Marten Diets

Prey isotope values.—Isotope values of small mammals exhibited some spatial and temporal variation (Figs. 6-8). Isotopic values for red-backed voles in Yakutat were different from those captured on Point

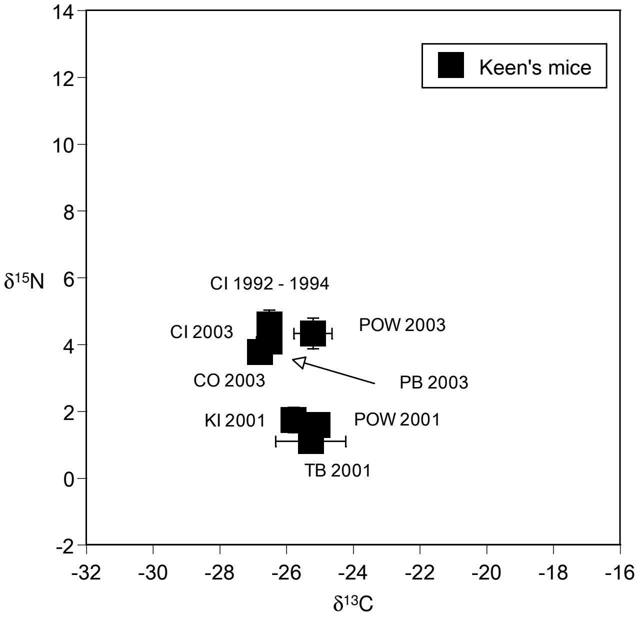

Figure 7. Values of δ^{13}C and δ^{15}N (mean ± SE) for Keen's mice in Southeast Alaska. CI is Chichagof Island, CO is Point Couverden, KI is Kuiu Island, PB is Portage Bay on Kupreanof Island, POW is Prince of Wales Island, and TB is Thomas Bay.

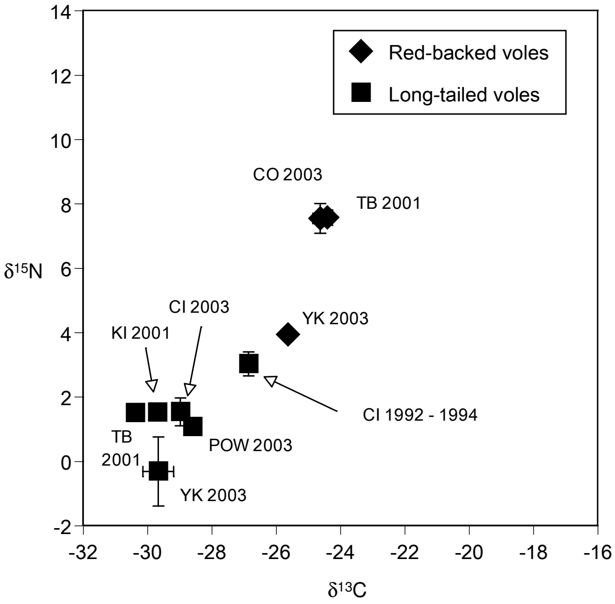

Figure 6. Values of δ^{13}C and δ^{15}N (mean ± SE) for red-backed and long-tailed voles in Southeast Alaska. CI is Chichagof Island, CO is Point Couverden, KI is Kuiu Island, POW is Prince of Wales Island, TB is Thomas Bay, and YK is Yakutat.

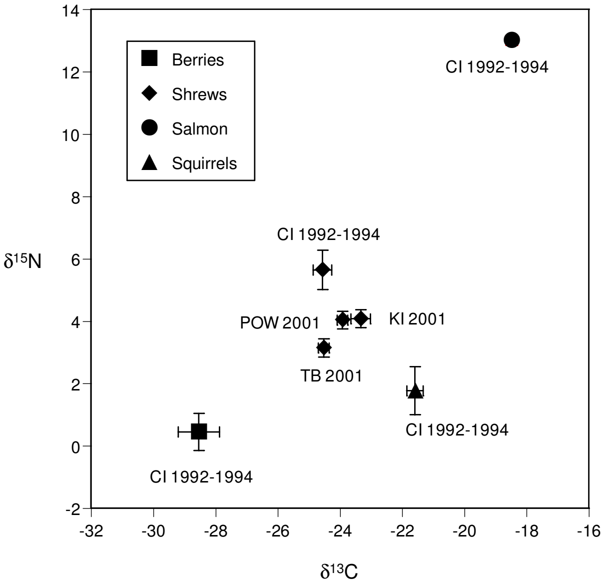

Figure 8. Values of δ^{13}C and δ^{15}N (mean ± SE) for salmon, squirrels, berries, and shrews in Southeast Alaska. CI is Chichagof Island, CO is Point Couverden, KI is Kuiu Island, PB is Portage Bay on Kupreanof Island, POW is Prince of Wales Island, and TB is Thomas Bay. .

Couverden and Thomas Bay (K nearest-neighbor randomization test; $P < 0.001$) but the latter two were not ($P = 0.313$). Long-tailed voles did not significantly differ among locations (K nearest-neighbor randomization test; $P = 0.543$). However, long-tailed voles captured on Chichagof Island in 1992-1994 did differ from those caught during this study (Fig. 6; $P < 0.001$). Isotopic values of long-tailed voles were different than those of red-backed voles as well as from those of Keen's mice ($P < 0.001$). Keen's mice exhibited two clusters, which differed from each other ($P < 0.001$) (Fig. 7). One cluster included Chichagof Island (both 1992-1994 and 2002), POW in 2003, Kupreanof Island (PB) and Point Couverden (CO), whereas the second cluster included POW in 2001, Thomas Bay (TB), and Kuiu Island (KI; Fig. 7). In addition, Keen's mice from the first cluster did not significantly differ from red-backed voles from Yakutat (Fig. 6, 7). Shrews in all locations had similar isotopic signatures except for Thomas Bay (CI-TB $P = 0.0004$; KI-TB $P = 0.038$; POW-TB $P = 0.035$) (Fig. 8).

Diet composition.—We collected blood or small tissue samples for stable isotope analysis from 77 of 89 (87%) martens captured including individuals caught in >1 year. The proportion of prey items in the diet of martens differed among the sampling locations and through time (Table 7). The average proportion of long-tailed and red-backed voles in the diet of martens ranged between 0.07 to 0.46 and 0.07 to 0.36 respectively (Table 7). For Chichagof Island, the consumption of long-tailed voles appeared to track their abundance ($r = 0.76$, $P = 0.008$). The same relationship was clear when all sites and sampling years were included in the analysis ($r = 0.64$, $P = 0.01$). The average proportion of Keen's mice in the diet of martens ranged from 0.02 to 0.28 even in locations or periods where voles were low (Table 7). For Chichagof Island, the consumption of Keen's mice did not appear to track vole abundance ($r = 0.006$, $P = 0.98$). Similarly, when all sites and times were included in the analysis, we found no correlation between the abundance of voles and the consumption of Keen's mice ($r = -0.11$, $P = 0.89$). Usually martens consumed a higher proportion of voles than Keen's mice, and more Keen's mice than squirrels. The exception was Etolin Island where about 30% of the diet was squirrels. We could not separate the proportions of red and flying squirrels in the diet, so where their ranges overlap, the squirrel portion of the diet likely includes both species. The proportion of squirrels in the diet averaged 0.127 for all sites and ranged between 0.009 and 0.3. We found no correlation between vole abundance and proportion of squirrels in the diet ($r = 0.08$, $P = 0.78$). Berries were consumed on all study areas (average of 0.179 for all sites with a range of 0.067 – 0.344), but usually in greater proportion in areas where voles were abundant than where they were scarce. When all sites were considered together, we found a marginal positive correlation between vole abundance and proportion of berries in the diet ($r = 0.494$, $P = 0.07$).

On study areas where voles were scarce, salmon was the dominant food item in fall (Table 7). Where salmon was the most common food item, martens also ate mammalian prey, but Keen's mice usually made up a greater proportion of the diet than voles or squirrels (Table 7). Both the values of $\delta^{15}N$ (Fig. 9) and proportion of salmon in the marten diets (Fig. 10) were related to the abundance of voles. When vole numbers were lower than 1 animal per 100 trap-nights, martens appeared to consume large amounts of salmon. The relationship between values of $\delta^{15}N$ and number of vole captures per 100 trap-nights was best

Table 7. Proportions of prey items in the diet of martens in different locations and years in Southeast Alaska. Proportions were determined from stable isotope values and the program IsoSource. Vole abundance is presented as number of captures of both long-tailed and red-backed voles per 100 trap-nights.

Location	Year	Vole numbers	Long-tailed voles		Red-backed voles		Keen's mice		Salmon		Squirrels		Berries	
			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Chichagof Island	1991	0.33	0.101	0.075			0.136	0.100	0.579	0.030	0.074	0.019	0.111	0.082
	1992	0.00	0.089	0.067			0.121	0.089	0.592	0.028	0.096	0.018	0.098	0.073
	1993	0.33	0.173	0.126			0.234	0.169	0.148	0.053	0.225	0.029	0.190	0.138
	1994	3.00	0.291	0.189			0.181	0.119	0.049	0.039	0.120	0.038	0.344	0.196
	1995	7.67	0.463	0.196			0.086	0.064	0.027	0.022	0.470	0.037	0.227	0.195
	1996	3.00	0.204	0.144			0.255	0.180	0.125	0.057	0.193	0.032	0.224	0.157
	1997	0.67	0.153	0.112			0.206	0.149	0.213	0.047	0.261	0.026	0.167	0.122
	2002	9.33	0.251	0.167			0.211	0.142	0.071	0.040	0.186	0.037	0.282	0.177
	2003	4.67	0.232	0.167			0.276	0.148	0.131	0.053	0.107	0.041	0.253	0.182
Etolin Island	2001	4.30	0.202	0.139	0.070	0.053	0.131	0.103	0.040	0.031	0.297	0.029	0.259	0.145
Kuiu Island	2001	0.20	0.094	0.070			0.192	0.139	0.379	0.007	0.237	0.066	0.098	0.072
	2002	0.00	0.295	0.111			0.022	0.020	0.529	0.008	0.009	0.010	0.145	0.115
Kupreanof Island	2002	0.00	0.153	0.100			0.223	0.152	0.324	0.009	0.144	0.071	0.156	0.105
	2003	0.00	0.065	0.049			0.085	0.063	0.626	0.018	0.158	0.013	0.067	0.050
Point Couverden	2003	16.30	0.128	0.097	0.200	0.143	0.199	0.154	0.156	0.078	0.147	0.040	0.170	0.126
Prince of Wales Island	2001	0.00	0.138	0.100			0.240	0.173	0.402	0.049	0.056	0.033	0.165	0.120
	2002	0.00	0.124	0.090			0.215	0.156	0.461	0.044	0.057	0.030	0.148	0.108
	2003	0.20	0.165	0.112			0.273	0.197	0.283	0.055	0.099	0.038	0.189	0.137
Thomas Bay	2001	4.60	0.107	0.078	0.232	0.165	0.162	0.112	0.234	0.092	0.130	0.069	0.134	0.103
	2002	6.70	0.188	0.109	0.213	0.134	0.155	0.104	0.134	0.074	0.099	0.065	0.211	0.145
Yakutat	2003	13.40	0.322	0.130	0.355	0.210	0.124	0.076	0.137	0.081	0.062	0.029	0.229	0.163

described by the regression: $y = 7.306x^{-0.048}$ (4), where y = $\delta^{15}N$ of marten diets, and x = vole abundance ($r^2 = 0.527$, $P < 0.001$, Fig. 9). The relation between percent salmon in the diet and number of vole captures per 100 trap-nights was best described by the regression: $y = 0.187x^{-0.137}$ (5), where y = percent salmon in marten diets and x = vole abundance ($r^2 = 0.657$, $P < 0.001$, Fig. 10).

We found that the biomass of long-tailed voles and Keen's mice best predicted marten density according to the regression model: $y = 1.777 + 0.007x_1 - 0.008x_2$ (6); where y = marten density (per 1000 ha), x_1 = biomass of long-tailed voles (per 100TN) (P = 0.006), and x_2 = biomass of Keen's mice (per 100TN) (P = 0.082) (r^2 = 0.44, P = 0.016). Of the other food variables, the ungulate index nearly entered the model (t = 1.40, P = 0. 19). The abundance of red-backed voles was not a significant predictor of marten abundance (t = -0.509, P = 0.62).

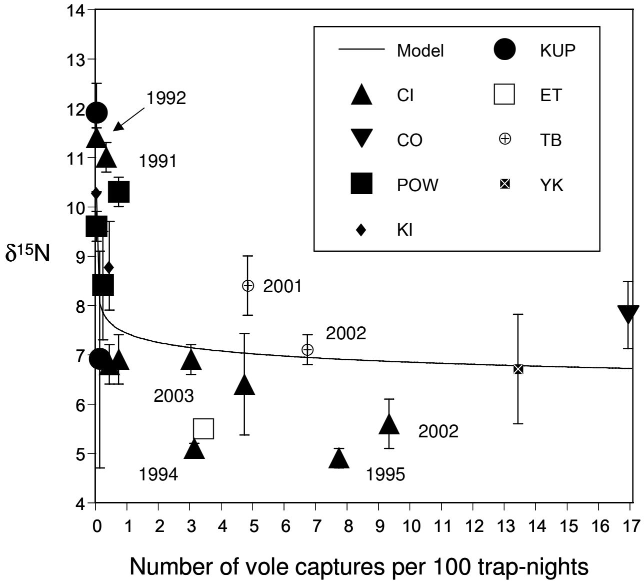

Figure 9. Relation between values of $\delta^{15}N$ (mean ± SE) and number of voles captured per 100 trap-nights in Southeast Alaska. Vole numbers are calculated as the sum of both long-tailed and red-backed voles. CI is Chichagof Island, CO is Point Couverden, ET is Etolin Island, KI is Kuiu Island, KUP is Kupreanof Island, POW is Prince of Wales Island, TB is Thomas Bay and YK is Yakutat.

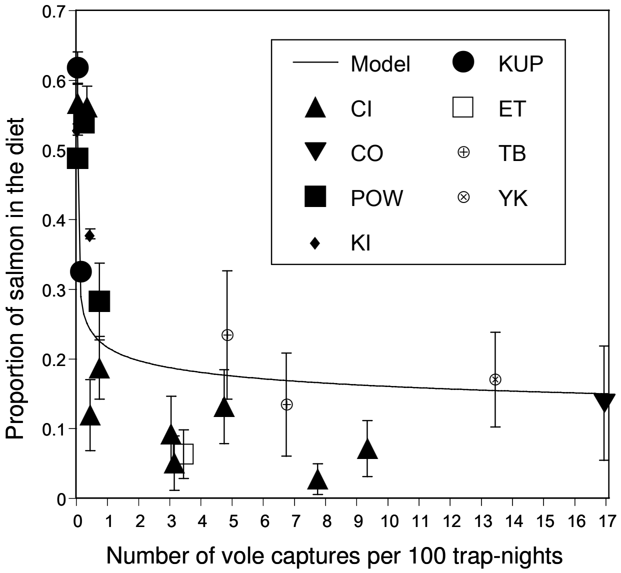

Figure 10. Relation between percent salmon in the diet, as determined with the program IsoSource (mean ± SE) and number of voles captured per 100 trap-nights in Southeast Alaska. Vole numbers are calculated as the sum of both long-tailed and red-backed voles. CI is Chichagof Island, CO is Point Couverden, ET is Etolin Island, KI is Kuiu Island, KUP is Kupreanof Island, POW is Prince of Wales Island, TB is Thomas Bay and YK is Yakutat.

In a combined food and landscape habitat model, marten density was best predicted by the regression: $y = 1.381 + 0.005x_1 + 5.14x_2$ (7); where y = marten density (per 1000 ha), x_1 = biomass of long-tailed voles (per 100TN) (P = 0.025), and x_2 = SDI (P = 0.075) (r^2 = 0.65, P = 0.015). In this combined model, the biomass of Keen's mice dropped out (P = 0.123) and was replaced with SDI (P = 0.075). As previously reported, SDI was a significant predictor of Keen's mice. Thus, marten density was best predicted by the abundance of long-tailed voles and the more proportional distribution of habitat patches.

DISCUSSION

We found that marten densities in Southeast Alaska, as previously documented for Chichagof Island (Flynn and Schumacher 1996), depended on the abundance of long-tailed voles in areas of similar habitat composition. In addition, we demonstrated that a greater biomass of Keen's mice clearly did not contribute to increased marten abundance. Marten density also appeared greater in less fragmented landscapes based on several spatial variables. These observations were consistent with other studies that demonstrated that at least 3 factors can strongly influence the density of martens on a landscape: amount and distribution of older forest (Thompson and Colgan 1987, Hargis and Bissonette 1997, Chapin et al. 1998, Potvin et al. 2000), prey abundance (Weckwerth and Hawley 1962, Thompson and Colgan 1990), and fur trapping (Strickland and Douglas 1987, Katnik et al. 1994). In contrast with our predictions, however, we did not find a relation between marten densities and the diversity of the prey fauna.

Despite the observation that our traplines were similar in habitat characteristics to the planned OGRs at each location, it appeared that those large OGRs would likely not support the 25 females assumed in TLMP (U.S. Forest Service 1997), even in years of high abundance of long-tailed voles. Although our estimates of marten densities may be imprecise, the upper 80% CIs for Etolin, Kuiu, Kupreanof, POW, and Yakutat did not include 25 females. Thus, OGRs in these areas would likely not support the 25 females assumed in TLMP. Additionally, the TLMP conservation strategy referred to resident, adult females, whereas our estimates included all females including juveniles. Similarly, male martens were only slightly more abundant in our study areas, with projected numbers ranging from 4 (Kuiu Island) to 38 (Thomas Bay in 2002). Again, the upper 80% CIs for several study areas, including POW, Etolin, Kuiu, and Yakutat, did not include 25 individuals. Nonetheless, whether 25 resident females are required or sufficient for the maintenance of viable populations in OGRs as well as to ensure the persistence of metapopulations is unclear.

Our density estimates may be imprecise because we assumed that the probability of capture previously observed on Chichagof Island was appropriate for other areas in Southeast Alaska. On Chichagof Island, trap habituation may have resulted in an upward bias in capture probabilities. In that case, our density estimates for other study areas would be slightly low. Unfortunately, we had too few recaptures in this study and are unable to test the effects of habituation on capture probabilities. Nonetheless, by incorporating the error terms associated with both capture probability and home-range size observed in Chichagof Island, we probably obtained a robust estimate of marten densities for our other study areas.

Two lines of evidence suggested that our density estimates for all 8 study areas were reasonable. Although number of captures per 100 trap nights (capture rate) varied greatly among study areas (from 0.4 captures/100TN on Etolin Island in 2002 to 5.8 captures/100TN on Chichagof Island in 2002) and among years, this capture rate was relatively consistent within each area where we trapped in subsequent years and the ranking of capture rates among study sites was similar. For example, capture rates for Chichagof Island and Thomas Bay were consistently the highest and Kuiu Island and Kupreanof Island the lowest. POW was usually intermediate, but only slightly higher than Kupreanof. This observation is especially important given the low recapture rates and suggests that capture rates represented abundance rather than habituation of a few individuals. In addition, ADFG marten fur sealing records were generally consistent with our density estimates after accounting for the distribution of road systems and the location of population centers (such as permanent communities and temporary logging camps) as a measure of effort. For example, over the last 12 years trapper harvest on Chichagof Island, where we estimated a high density of martens, has often been quite high despite a ban on use of motorized land vehicles for trapping on federal lands. Despite extensive road systems, we found few records of high harvests on Kuiu, Kupreanof, or Etolin islands where we estimated low densities of martens. In contrast, we estimated relatively high densities of martens at Thomas Bay and Point Couverden, but harvest in these areas has been relatively low. Both areas have limited road systems and can be difficult to access in winter. Although we also estimated relatively low densities of martens on POW, the north-central portion of the island has often produced relatively high harvests. POW is the largest island in Southeast Alaska, and it has over 5000 residents and ~5000 km of roads. We believe that high harvest there results from high trapper effort.

We believe fur trapping had little influence on our capture success at most study sites because few martens were trapped in the vicinity of those sites during the winters prior to and during our surveys. A few exceptions, however, merit discussion. In Yakutat, conversations with residents during our live-trapping survey indicated that 50-60 martens were harvested there during the previous winter instead of the 21 martens reported in ADFG sealing records. Despite occurring on the mainland, the population of martens in Yakutat is isolated by mountains and glaciers, and therefore may respond more like an island population. Such level of harvest could have reduced our capture success and depressed the density estimate for this area. Harvest also occurred on the Kuiu Island study area during the winter before our 2001 survey when 17 martens were taken. Nonetheless, there was no harvest during the next winter, and our 2002 survey resulted in fewer captures than in 2001. Therefore we feel it is unlikely that the harvest that occurred in 2001 greatly influenced our results. Finally, despite no trapping of martens on our study area, marten harvest on north-central POW during 2000 exceeded the mean harvest for that area by 155 animals. Although this high level of harvest should not have affected the number of martens residing on the study area, it could have reduced the number of transient martens present during our 2001 survey. If that was the case, our density estimate for 2001 may be biased low.

Although our traplines did not always completely overlap the designated OGRs, we found only minor differences in habitat composition and spatial patterns between them. We anticipated greater proportions of clearcut habitat in our study areas than in OGRs because one of the criteria for study areas was that they have $\geq$25 km of drivable road; and roads are built to access areas for logging. In contrast, guidelines for designing OGRs specify that they contain a minimum of clearcut habitat (U.S. Forest Service 1997). Although our study areas often had about twice the amount of clearcuts as nearby OGRs, this habitat type was a relatively small proportion of landcover at all sites (<12%). For example, the Chichagof Island and Kuiu Island study areas had about the same proportion of clearcut habitat, but much different marten capture rates. Therefore, we believe the greater proportions of clearcuts in study areas compared to OGRs likely did not bias our estimates of marten density in OGRs.

Our observations suggested that marten densities did not vary by composition of forested-habitats within the narrow range sampled. By design the OGRs, and thus the study areas, have minimum habitat composition requirements for productive old-growth forest, i.e., 50% productive old-growth forest and 25% VC5$^+$. These minimums were developed based on previous studies in other forests that described habitat requirements for martens (U.S. Forest Service 1997). Our data suggested that these minimums are probably appropriate.

The measures of spatial patterns of habitat that emerged from our analysis were representative of what has been established elsewhere as high quality habitat for martens. The prevailing view is that the highest densities of martens are associated with areas of continuous late-successional forest (reviewed by Buskirk and Ruggiero 1994). Working in landscapes heavily fragmented by logging, Snyder and Bissonette (1987) and Chapin et al. (1998) found that both size and isolation of residual forest stands influenced the use of those stands by martens. Hargis and Bissonette (1997) reported that naturally fragmented landscapes and landscapes fragmented by logging supported lower densities of martens than landscapes with continuous forest. Potvin et al. (2000) found that forest fragmentation was lower in actual marten home ranges than in randomly placed home ranges on an industrial forest landscape. In our study, the number of habitat patches was negatively correlated with marten density. Thus, marten densities were greater in less fragmented study areas. In contrast, SDI was positively correlated with marten densities. We interpret these variables to collectively indicate that study areas with larger and more evenly distributed patches of forest supported higher densities of martens than areas with more fragmented forest. Insufficient amounts of productive forest in the Etolin Island study area likely had little influence on the low marten capture rate experienced there. The proportions of forest in volume classes $\geq$4 and VC5$^+$ on the Etolin Island study area differed by only 1.8% (67 ha) and 6.1% (374 ha), respectively, from proportions at the Thomas Bay study area, which was of similar size and had among the highest marten densities.

We were surprised that marten densities were not clearly influenced by the diversity of the small mammals fauna in the different study areas. We expected that a more diverse fauna would result in a consistently greater quantity of available food that would enhance reproduction and survival in martens. A more diverse prey base should provide alternative foods when preferred foods were less available. Our multiple-regression model (equation 3), however, only identified the biomass of long-tailed voles as a positive predictive variable of marten densities. Our ungulate index was positively correlated with marten density, but didn't enter into the regression model at $\alpha = 0.1$, probably because our ungulate index was correlated with long-tailed vole abundance. Although Keen's mice were a significant negative variable in the regression model, we do not believe that the abundance of Keen's mice actually impacted marten populations, but their abundance was correlated with other factors. Our data did show that the abundance of red-backed voles had no relationship with marten densities. Unfortunately, we were unable to assess the availability of red- and northern flying squirrels to martens because of financial and logistical constraints. Nonetheless, the relatively low proportion of squirrels (of either or both species) in the diet of martens as calculated from stable isotope ratios, and the lack of relation between voles abundance and the relative consumption of squirrels suggest that they too may play a lesser role in determining the abundance of martens in Southeast Alaska.

Because isotope values of small mammals exhibited some spatial and temporal variation in Southeast Alaska, our ability to extrapolate from one area to another may be limited. Even in the same location (Chichagof Island), isotopic values changed between sampling years. These differences were not consistent though. For example, isotopic values of long-tailed voles on Chichagof Island in 1992 – 1994 were different than those in 2003, but that pattern was not detected in values of Keen's mice. Ben-David et al. (2001) cautioned that an isotopic value observed in primary and secondary consumers is an emergent property of multiple ecological processes that can vary with changing environmental conditions (e.g., nutrient and water availability for plants; community composition of plants and plant quality; nutritional condition of the animal, etc.). Thus, future studies into the nutritional ecology of martens (as well as other animals) will require full sampling of all possible foods during the entire duration of the study. In this study, we used isotopic values of squirrels, berries, and salmon from Chichagof Island for all other locations. Our use of data for salmon is likely appropriate because salmon acquire most of their biomass at sea (Heard 1991), and the values we obtained for fish caught on Chichagof Island were comparable to other studies in other locations in the Pacific Northwest and Alaska (Kline et al. 1989, 1993, Hilderbrand et al. 1999, Naiman et al. 2002, Reimchen et al. 2002). Our use of isotopic values for berries and squirrels from Chichagof Island, however, as well as values of other prey items from different sites and periods may have biased our results. Nonetheless, because the spatial and temporal variation was sporadic we feel that the broad conclusions we draw from our data are valid.

Results from the isotope analysis, combined with the observation that biomass of long-tailed voles was a predictive variable of marten density, suggest that similar to our previous findings from Chichagof Island (Ben-David et al. 1997), martens in different locations and across time relied heavily on voles. Unfortunately, because we had only 3 locations with both vole species, our ability to unequivocally establish the relative importance of each vole species was limited. Other studies found that martens preferred *Microtus* species to *Clethrionomys* spp. (Weckwerth and Hawley 1962, Buskirk and MacDonald 1984). Whether this preference relates to habitat association of the 2 species, their behavior, or energetic profitability is unclear. Red-backed voles are usually significantly smaller (28 – 34 g) than long-tailed voles (37 – 57 g; Burt and Grossenheider 1976, this study), and thus may provide lower energetic returns. Interestingly, our results suggested that the consumption of Keen's mice by martens remains relatively low even when vole numbers are low. The lack of correlation between capture rates of Keen's mice and long-tailed voles suggested that martens could have switched to feed on Keen's mice when numbers of long-tailed voles were low, but did not necessarily do so. As with the result from our multiple regression model (equation 6), this observation indicated that Keen's mice might not constitute an important alternative prey for martens in Southeast Alaska. That marten body condition (BCI) was not correlated with rodent biomass may be, in part, a result of the fact that most of the rodent biomass in our study was derived from the mean capture rates of Keen's mice. Unfortunately, our low capture rates of long-tailed voles precluded evaluation of the effects of the biomass of this species alone on the BCI of martens.

Similar to our earlier finding from Chichagof Island (Ben-David et al. 1997), when vole numbers were low, salmon was the main source of food for martens during fall. In this study we were able to identify a threshold of vole abundance at which martens switched to feed on salmon. This threshold is about 1 vole per 100 TN. The model of proportion salmon in the diet relative to vole abundance (equation 2), explained more of the variation than the one with values of $\delta^{15}N$ (equation 1) probably because the calculation of proportion of salmon in the diet (with the program IsoSource, Phillip and Gregg 2003) accounted for the variation in isotopic values of voles. Although both models were highly significant and explained 53 – 66% of the variance in the data, other factors could have influenced the consumption of salmon by martens in the different locations and years. Those factors can be the distribution of salmon streams in the study areas, the abundance of other foods such as squirrels, and berries, as well as potential differences in isotopic values of foods (see discussion above). Although the effects of consumption of salmon on survival and reproduction of martens remains unclear, planning of OGRs should ensure the inclusion of salmon streams within their boundaries.

The role of ungulate carrion in supporting populations of martens in Southeast Alaska is poorly understood. In this study, ungulate density was nearly a significant predictor of marten density (equation 6), but because ungulate carrion is scarce at the time of our sampling we did not include this variable in our diet estimation. We suspect that ungulates may be more important in late winter and spring when carrion from winter-killed animals is available. Indeed, our study on Chichagof Island (Ben-David et al. 1997) revealed that deer composed up to 32% of the diet of martens in that season. We suspect that the availability of ungulate carrion affects marten densities through reproduction rather than survival. In spring, blastocysts, which are embryos in diapause since the previous summer, implant in the uterus and begin to develop (Mead 1989). Because active pregnancy is an energetically demanding time for mammals (Robbins 1993), nutrition from ungulate carrion may enhance reproductive rates in martens. The effects of ungulate carrion on reproduction in martens merits further investigation.

In our original study design, we did not fully consider the difference in size of the different small mammal populations on the island and mainland sites. Long-tailed voles weigh twice as much as red-backed voles, and Keen's mice on Chichagof Island were significantly heavier than mice from other study areas. Consequently, at similar densities, islands inhabited by the larger-bodied small mammals could provide a greater biomass of prey for martens than islands or mainland sites with smaller individuals. This observation could explain why a high diversity of potential prey items alone did not ensure higher numbers of martens. Our marten trapping results generally support this idea. Chichagof Island had the most numerous and productive population of martens of the 8 areas sampled, and it also was populated by the largest bodied small mammals, which were relatively numerous. Therefore, body mass and abundance must both be considered when interpreting the value of small mammals as prey for martens. Where long-tailed voles were abundant, we caught high numbers of martens. Where long-tailed voles were scarce, but red-backed voles abundant, we caught moderate numbers of martens, and where voles were scarce, we caught few martens.

MANAGEMENT IMPLICATIONS

In Southeast Alaska, populations of martens on islands and areas of the mainland, isolated by glaciers and major rivers, are demographically independent because martens generally do not cross water barriers (Buskirk and Ruggiero 1994). These populations also show genetic isolation (Stone et al. 2002, Small et al. 2003). Because the demographic characteristics of populations of martens appeared related to the abundance of prey (Thompson and Colgan 1987, this study) and because assemblages and abundances of potential prey differ by island (MacDonald and Cook 1996, this study) and through time (Flynn and Schumacher 2001), conservation measures for martens should be tailored to specific populations, not for the TNF as a whole.

Our findings indicated that on most study areas, even in years of high abundance of long-tailed voles, large OGRs would likely not support the 25 female martens assumed in TLMP (U.S. Forest Service 1997). Therefore, for populations of particular concern, it will be important to understand the range of these fluctuations when developing future conservation plans. The conservation strategy in TLMP recognized the importance of managing for periodic lows in marten populations. Nonetheless, until more information becomes available on the nature of these fluctuations in different parts of the TNF, such conservation plans will be deficient. Although our study captured some of the spatial and temporal variation in marten densities in the Alexander Archipelago, we only visited sites in 1 – 3 consecutive years, and therefore did not capture the full range of fluctuations in marten population. In addition, whether 25 resident females are required or sufficient for the maintenance of viable populations in OGRs as well as to ensure the persistence of metapopulations remains unclear.

Our findings also suggested that the habitat suitability model used to evaluate the effects of timber management on martens probably overestimates the number of martens. The current model, developed over a decade ago from data collected on Chichagof Island, assigns densities of martens to habitat types based only on vegetative features and does not take into account the differing assemblages and abundances of prey found throughout the TNF. Our data illustrates the need to include information on the dynamics of prey populations, especially long-tailed voles, and the distribution of salmon streams on the landscape in future improvements of this habitat suitability model.

Based on our findings, the efficacy of the conservation measures for martens in the Forest Plan will require additional consideration. For populations of martens where OGRs and lands in other non-development LUDs are unlikely to support a sufficient number of females and where further timber harvest is planned, additional conservation measures may be necessary. We suggest that an increase of the size and proportion of higher quality habitat of OGRs would likely result in increase in the number of martens in individual OGRs. As an initial step in re-evaluating the conservation strategy for martens on the TNF, we recommend mapping all large and medium OGRs, determining their size and forest composition, and applying marten density estimates for locations with available data. Many planned large OGRs will likely be larger than the minimum size of 16,200 ha. Therefore, even with low densities, larger than required OGRs may support the minimum number of female martens. Because of the apparent importance of salmon as an alternate food in years of low vole abundance (Ben-David et al. 1997, this study), the inclusion of salmon streams within OGRs may also increase carrying capacity for martens.

Finally, increased connectivity among OGRs would increase the likelihood that populations will function as metapopulations and OGRs would be repopulated by immigration after local extinctions have occurred. Little information exists on the proper design of corridors or their use by martens. However, we suspect that wider forested corridors would be more likely used by martens for dispersal. On islands where marten numbers are low, designating wider corridors between OGRs than required by TLMP may enhance viability of the population. Also, roads through corridors may reduce their effectiveness because fur trappers often use them.

Management of matrix lands may hold the greatest potential for enhancing conservation of martens. On a forest-wide basis, about 57% of the timber production land is unsuitable for harvest (U.S. Forest Service 1997). Mapping the distribution and vegetative cover of these lands would be an initial step in providing information about potential habitat for populations of martens when TLMP is fully implemented. For populations where marten numbers are low and planned logging will threaten viability, several changes to forest management could minimize the effects of logging. Yarding logs by helicopter would reduce the need to build roads and thereby maintain refugia from fur trapping. Using partial harvest instead of clearcutting could also maintain habitat value for martens while allowing some timber harvest. To most benefit martens, the goal of partial harvesting should be to maintain productivity for small mammals, especially voles, within harvested stands. To do this the productivity of plants beneath the forest canopy must be maintained as a food source for small mammals. On study plots throughout Southeast Alaska, Deal (2001) found that partial harvesting prescriptions retaining >50% of the basal area of a stand including trees in all size classes prevented establishment of a new tree cohort and retained understory plant communities similar to old-growth forest. Widespread use of partial harvesting prescriptions instead of clearcutting on lands managed for timber production could significantly enhance conservation of martens. Finally, because unfragmented forest supports the highest densities of martens (Snyder and Bissonette 1987, Chapin et al. 1997, 1998, Hargis and Bissonette 1997, Potvin et al. 2000), we recommend clumping timber harvest to maintain the largest possible blocks of uncut forest.

FUTURE DIRECTION

The past 3 years of research has documented that densities of most marten populations in the TNF were lower than assumed in the TLMP conservation strategy for this design species. Our data indicated that by consuming seasonally available salmon, martens in areas where voles are scarce could maintain body condition similar to martens in areas with abundant voles. However, the low densities of martens in these areas suggest that availability of food at other times of year could affect the dynamics of these populations through survival and reproduction. Therefore, understanding the relation between diet, body condition, reproduction and survival in martens in relation to the availability of small mammal and other prey at other times of the year may provide insight into the frequency and amplitude of fluctuations in the marten numbers.

Because of the high spatial and temporal variability in marten densities that we found across the TNF, more study sites should be sampled in the future to better clarify the effects of habitat and diversity of prey assemblages on marten population dynamics. Two large islands in northern Southeast (Admiralty and Baranof islands) should be surveyed to increase samples sizes for islands with relatively simple prey fauna. These islands are inhabited by other vole species, i.e. tundra (*Microtus oeconomus*) and meadow voles (*Microtus pennsylvanicus*). ADFG fur sealing records indicate that martens may reach similar densities on northern Baranof Island as they occur on Chichagof Island, suggesting that these voles may function like long-tailed voles. Also, ADFG deer pellet-group survey data indicates that northern Baranof and Admiralty islands support densities of deer similar to Chichagof Island. Abundances of tundra vole populations and their contribution to marten diets have not been studied. Admiralty Island, where martens appear less abundant than on Chichagof or Baranof Islands, also supports high numbers of deer, but is populated by meadow voles. These islands are in close proximity, have similar topography, and aside from species of voles, support similar assemblages of prey species. An investigation of marten abundance, diets, and prey availability on these islands would enhance our understanding of the relative value of the 3 species of voles for martens. Also, the Southeast Mainland showed large variability in marten numbers, suggesting that expansion of sampling is also merited there.

On Chichagof Island during the 1990's, populations of small mammals and martens peaked at about 6-year intervals. On other island and mainland sites, small mammals and thus martens may fluctuate at different intervals. Additional years of data in each study area would allow better estimates of the range of temporal fluctuations in marten densities.

Because marten densities were best predicted by catch rates of long-tailed vole and Keen's mice along with ungulate abundance, surveys of these species would provide useful information on the likely status of marten populations. Long-tailed voles might be considered a keystone species (Simberloff 1998) because of their influence on other species, particular small predators. For areas with significant future timber harvest planned, monitoring of small mammals would provide insight into possible marten population status and trends. Generally, the abundance of small mammals is easier to estimate than other mammals, but more research into cost-effective sampling approaches would be important. Our small mammal sampling effort was quite modest, but still provided useful results. In addition, the effects of partial harvesting, which may cause little change to the understory vegetation compared to unharvested stands (Deal 2001), on small mammal communities merits further investigation.

Finally, if OGRs do not support the minimum number of females as stated in TLMP, unrestricted movement among OGRs may ameliorate the effects of local extirpation. Marten populations in harvested landscapes probably behave as metapopulations where individuals disperse among adjacent reserves. Such dispersal through connecting corridors would maintain gene flow, ensure maintenance of genetic variability, and reduce the risk of local extinction. The ability of martens to disperse across open spaces, however, is unclear. Future work should concentrate on estimating dispersal rates of martens through the harvested matrix. In such studies, martens could be tagged and their movements monitored to study dispersal. Alternately or in conjunction, DNA analysis could be used to explore dispersal patterns in relation to fragmented landscapes by evaluating gene flow, number of migrant per generation, as well as dispersal distances with assignment tests (Cornuet et al. 1999, Blundell et al. 2002). This investigation of dispersal and gene flow in populations of martens would also allow for the determination of corridor characteristics necessary for maintaining connectivity of marten populations.

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APPENDICES

Appendix A. Summary of martens live-captures at 8 study sites in Southeast Alaska, 2001-2003.

Study area	Marten number	Age first capture[a]	Sex	Year(s) captured			Mo./Yr. harvested
				2001	2002	2003	
Chichagof Is.	CI-188	8	F			X	
	CI-312	3	M		X		
	CI-313	0	F		X		
	CI-314	0	M		X		
	CI-315	0	M		X		
	CI-316	0	F		X		
	CI-317	1	F		X		
	CI-318	0	M		X		
	CI-319	0	F		X		
	CI-320	0	M		X		
	CI-321	1	F		X	X	
	CI-322	4	F		X		
	CI-323	0	F		X		
	CI-324	0	M		X		
	CI-325	2	M		X		
	CI-326	2	F			X	
	CI-327	0	M			X	
	CI-328	0	M			X	
	CI-329	Ad	M			X	
	CI-330	1	F			X	
	CI-331	0	F			X	
	CI-332	0	M			X	
	CI-333	9	F			X	
Etolin Is.	ET-01	4	F		X		
Kuiu Is.	KI-01	0	M	X	X		
	KI-02	4	F	X			
	KI-03	5	F	X			
	KI-04	1	F		X		
Kupreanof Is.	KUP-01	1	M		X		1/03
	KUP-02	0	F		X		
	KUP-03	1	M		X		1/03
	KUP-04	1	M		X		
	KUP-05	3	M		X	X	1/03
	KUP-06	0	M			X	1/03
	KUP-07	0	M			X	1/03
	KUP-08	0	M			X	
	KUP-09	0	F			X	
	KUP-10	0	M			X	1/03

Appendix A. Continued.

Study area	Marten number	Age first capture[a]	Sex	Year(s) captured			Mo./Yr. harvested
				2001	2002	2003	
Point Couverden	C-01	1	F	X			
	C-02	Ad	M	X			
	C-03	1	F	X			
	C-04	0	M	X			
	C-05	4	M	X			
	C-06	2	F	X			
	C-07	0	F	X			
	C-08	0	M	X			
Prince of Wales Is.	POW-01	0	M	X			
	POW-02	Ad	F	X			
	POW-03	0	M	X			
	POW-04	Ad	F	X			
	POW-05	1	M	X			
	POW-06	0	M		X		
	POW-07	1	M		X		
	POW-08	1	M		X		
	POW-09	0	F		X		
	POW-10	0	M		X		12/02
	POW-12	6	F			X	
	POW-28	3	M			X	
	POW-29	0	M			X	
	POW-30	0	F			X	
	POW-31	0	M			X	
Thomas Bay	TB-01	2	M	X	X		12/02
	TB-02	0	M	X			
	TB-03	7	F	X			
	TB-04	4	M	X			
	TB-05	4	F	X			12/02
	TB-06	0	M	X			12/01
	TB-07	0	M	X			
	TB-08	2	F	X	X		
	TB-09	1	M	X			
	TB-10	0	M		X		12/02
	TB-11	0	M		X		
	TB-12	2	M		X		12/02
	TB-13	0	M		X		
	TB-14	0	F		X		12/02
	TB-15	1	M		X		
	TB-16	0	M		X		12/02
	TB-17	0	M		X		12/02
	TB-18	0	M		X		
	TB-19	1	F		X		12/02
Yakutat	Y-01	1	M			X	
	Y-02	4	F	X			
	Y-03	0	F	X			
	Y-04	0	F	X			
	Y-05	1	M	X			

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[a] Ages were determined by cementum annuli analysis. Adult/juvenile classifications based on skull characteristics examined in the field.

Appendix B. Mean captures/100 trap nights of mice and voles at 8 study sites around Southeast Alaska, fall 2001-2003. In each habitat category at each location, 2 Museum Special snap traps were set at 25 stations evenly spaced along a 360m-long transect and checked for 3 consecutive nights (150 trap nights). In some habitats, multiple transects were completed (*n* = number of transects).

		Habitat							
		Large/Medium MS Forest				Intermediate MS Forest			
Location	Year	*n*	Keen's mice	Long-tailed voles	Red-backed voles	*n*	Keen's mice	Long-tailed voles	Red-backed voles
Chichagof Island	2002	1	4.7	8.7	--	1	4.7	10.0	--
	2003	1	2.0	3.3	--	2	4.0	4.0	--
Etolin Island	2002	1	0	0	6.7	1	7.3	0	0
Kuiu Island	2001	1	5.3	0	--	1	4.0	0.7	--
		1	4.7	0	--	1	10.7	0	--
Kupreanof Island	2002	1	9.3	0	--	1	0	0	--
	2003	2	4.3	0	--	1	2.0	0	--
Point Couverden	2003	2	0.3	0	13.0	2	0	0	19.7
Prince of Wales Island	2001	1	9.3	0	--	1	4.0	0	--
	2002	1	3.3	0	--	1	4.0	0	--
	2003	2	4.4	0	--	2	9.7	0.3	--
Thomas Bay	2001	1	0.7	0.7	2.0	1	0	0	6.7
	2002	1	0.7	0	5.3	1	1.3	0	8.0
Yakutat	2003	2	0	0.7	12.7				

Appendix C. Habitat composition of 8 marten study areas and nearby OGRs in Southeast Alaska, 2001-2003. Habitat classes were derived from the U. S. Forest Service TIMTYP landcover GIS database.

	Study Areas							
Habitat	Chichagof Island	Etolin Island	Kuiu Island	Kupreanof Island	Point Couverden	Prince of Wales Is.	Thomas Bay	Yakutat
Marten study areas								
Non-forest	8.6	2.5	3.9	2.2	12.0	5.5	11.3	8.2
Clearcut	10.2	10.5	11.8	10.3	8.9	6.2	2.9	5.4
Scrub forest	21.3	46.4	18.7	33.5	22.9	32.7	17.4	18.3
VC 4	27.5	19.3	20.0	27.6	28.8	18.2	14.9	11.1
VC 5^{+}	31.8	21.4	40.7	25.8	27.4	37.4	27.5	57.1
Even-aged	0.6	0	4.8	0.6	0	0	26.1	0
Totals	100	100	100	100	100	100	100	100
OGRs								
Non-forest	17.6	16.2	6.6	10.9	33.3	7.2	7.7	11.7
Clearcut	4.8	1.7	7.7	0.9	4.3	0.6	2.6	0.1
Scrub forest	22.3	31.6	26.0	37.2	8.2	27.4	35.9	12.1
VC 4	15.7	20.3	24.3	30.2	20.7	17.7	19.6	7.6
VC 5^{+}	37.5	28.6	32.0	20.7	33.1	45.5	34.8	50.2
Even-aged	2.1	1.6	4.8	0.1	0.3	1.6	0	18.3
Totals	100	100	100	100	100	100	100	100

American martens and habitats in the Salt Lake Bay study area, Southeast Alaska.

Above photos by R. Flynn. Back cover photo by T. Schumacher.