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Resource selection varies with resource availability, predation risk, as well as inter- and intra-specific interactions. We investigated effects of demography on resource selection by martens (*Martes sp.*) on northern Kuiu Island in Southeast Alaska. Using demographic metrics, radiotelemetry, and measures of habitat availability we developed resource and latent selection functions for martens. Concurrently, we estimated abundance of small mammals and calculated the proportions of dietary biomass consumed by martens (during the fall) with stable carbon and nitrogen isotopes. Our investigation revealed that martens on Kuiu Island preferred habitat with closed-canopy old-growth forest in areas with higher densities of salmon streams and nearer to the coast. We found that juveniles consumed the highest proportion of salmon and used habitat with higher stream densities than adults. In contrast, adult females consumed the lowest proportion of salmon and used habitat further from the coast with lower densities of salmon streams. In 2011, the year with highest abundance and proportion of juveniles, all martens used habitats with higher densities of salmon streams and consumed more salmon than in other years. Thus, we demonstrate that demography should be considered when conducting resource selection analyses to correctly interpret findings and develop sound management decisions.

This paper was written as a manuscript to be submitted to the peer-reviewed Journal of Wildlife Management. It is written in plural to account for the contributions made by my co-authors. Rodney W. Flynn Research Coordinator for the Alaska Department of Fish and Game assisted with study design and data collection as well as shared previously collected data to augment data collected for this project. Merav Ben-David also assisted with study design and edited this thesis. I conducted the fieldwork, collected samples and performed the resource selection and stable isotope analyses, and wrote this thesis.

EFFECTS OF DEMOGRAPHY ON RESOURCE SELECTION BY MARTENS ON KUIU ISLAND, ALASKA

By

Carl H. Koch

A Thesis submitted to the Zoology and Physiology Department

and the University of Wyoming

in partial fulfillment of the requirements

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in

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Table of Contents

List of Tables

LIST OF FIGURES

May 6th, 2016

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RH: Koch et al.• Resource Selection by Marten

Effects of demography on resource selection by martens on Kuiu Island, Alaska.

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Abstract

Resource selection varies with resource availability, predation risk, as well as inter- and intra-specific interactions. We investigated effects of demography on resource selection by martens (*Martes spp.*) on northern Kuiu Island in Southeast Alaska. Using demographic metrics, radiotelemetry, and measures of habitat availability we developed resource and latent selection functions for martens. Concurrently, we estimated abundance of small mammals and calculated the proportions of dietary biomass consumed by martens (during the fall) with stable carbon and nitrogen isotopes. Our investigation revealed that martens on Kuiu Island preferred habitat with closed-canopy old-growth forest (as estimated by Interferometric Synthetic Aperture Radar difference; IfSAR) in areas with higher densities of salmon streams and nearer to the coast. We found that juveniles consumed the highest proportion of salmon and used habitat with higher stream densities than adults. In contrast, adult females consumed the lowest proportion of salmon and used habitat further from the coast with lower densities of salmon streams. In 2011, the year with highest abundance and proportion of juveniles, all martens used habitats with higher densities of salmon streams and consumed more salmon than in other years. Thus, we demonstrate that demography should be considered when conducting resource selection analyses to correctly interpret findings and develop sound management decisions.

Key Words demography, *Martes americana, Martes caurina,* Kuiu Island, resource selection, Southeast Alaska, stable isotopes.

Knowledge of resource selection by animals is essential for effective land management and wildlife conservation (Fretwell 1969, Southwood 1977, Rosenzweig 1981). Quantifying and mapping the distribution of habitat types that have the strongest effects on fitness is essential for managing endangered or threatened species and are especially important for habitat specialists (e.g., *Strix occidentalis, Oreamnos americanus, Ursus maritimus, Martes spp.*; (Gross et al. 2001, Dugger et al. 2005, Durner et al. 2009). Habitat selection studies are often designed to assess potential environmental impacts of anticipated anthropogenic activities such as mining, road construction, timber harvest, and other land use changes (Franzreb and Ohmart 1978, Soutiere 1979, Geier and Best 1980, Potvin et al. 2000, White et al. 2012, Moriarty et al. 2016). The goal of these studies is often to influence management decisions and aide in designing measures for mitigation of the negative impacts that occur when essential habitat is lost or fragmented (Keller and Pfister 1997, Harrison and Bruna 1999).

The availability of resources is often heterogeneous and single habitats may not provide all necessary needs of animals. For example, food availability and quality often change temporally and spatially (Owen-Smith 1994, Ben-David et al. 1997, Stone 2007). Thus, the distribution of animals on the landscape is a function of their movements in response to availability of resources and their particular daily, seasonal, and annual requirements during foraging, resting, predator avoidance, breeding and rearing of young, and intra- and interspecific competition. Animals are expected to spend more time in those habitats that provide the highest returns (i.e., high quality habitats) and move among patches in response to declining profitability (Brown and Morgan 1995).

Multiple studies have shown that negative density-dependence among conspecifics can influence selection of resources and affect the distribution of animals on the landscape

(McLoughlin et al. 2006). Similarly, increasing density of animals on the landscape can influence habitat selection when competition for limited resources causes subordinate animals (e.g., juveniles) to use lower quality resources (Van Horne 1981). In a study of Keen’s mice (*Peromyscus keeni*) populations on Prince of Wales Island in Southeast Alaska, Van Horne (1980) found strong segregation between juveniles and adults due to forced emigration of younger animals. In that study, high densities of adult Keen’s mice were associated with high quality habitats whereas juveniles mostly occurred in low quality ones (Van Horne 1980). Similarly, Fryxell et al. (1999) found that in Ontario, American martens (*Martes americana*) exhibited density dependent population growth, which they suggested was related to territorial behaviors. Indeed, density of conspecifics is often used as an indicator of habitat quality but can be a poor metric in the absence of other demographic information (Van Horne 1981, Van Horne 1983).

American martens (*Martes americana*) occurs in most of North America from New England and Newfoundland west to Montana and north to interior Alaska, while Pacific Martens (*M. caurina*) occur in the Pacific Northwest from Admiralty Island in Southeast Alaska to Oregon and Wyoming (Stone et al. 2002). One of two known contact zones, Kuiu Island, Southeast Alaska, is occupied by mostly hybrids of these two species of marten, and is the only known insular region of sympatry in North America (Stone et al. 2002, Small et al. 2003).

Habitat selection by American and Pacific martens has been evaluated in several studies across North America (Buskirk et al. 1994, Potvin et al. 2000, Bull et al. 2005, Hearn et al. 2010, Caryl et al. 2012). These studies demonstrated that individuals of both species prefer heterogeneous mature uneven aged forests over the even-aged stands that typically persist for many years after clear-cut logging has occurred (Buskirk 1992). In addition, association between denning and resting sites and mature uneven aged forests which provide cavities in large trees and coarse woody debris is commonly described (Buskirk 1984, Buskirk et al. 1989, Ruggiero et al. 1998, Schumacher 1999). Downed logs and other coarse woody debris, a characteristic of old-growth stands provide subnivean resting sites with concealment from predators as well as opportunities for foraging (Andruski et al. 2008). Although martens have been occasionally tracked with radiotelemetry to logged forest stands (Thompson 1994, Hearn et al. 2010), their aversion to open canopy habitats was quantified with telemetry as well as track counts along roads and trails (Cushman et al. 2011). Fuller and Harrison (2005) found that martens exhibited higher use of partially harvested stands of deciduous trees when leaves were present. In contrast, reduced overhead canopy closure during the leaf-out period resulted in lower marten use, likely because of limited access to small mammals. During that period martens increased reliance on snowshoe hares (*Lepus americanus*), which occurred at low densities in second-growth habitat (Fuller and Harrison 2005). Indeed, loss and fragmentation of old-growth habitats has been shown to negatively influence marten density and population growth (Thompson 1994).

Several studies report small mammals, especially voles (*Microtus* and *Myodes*) as an important food resource and preferred prey of martens (Buskirk and MacDonald 1984, Flynn and Schumacher 2009). Food availability (especially small mammals) has been linked to numerical responses in several marten studies (Thompson and Colgan 1987, Flynn and Schumacher 2009, Jensen et al. 2012). Lower ovulation rates were found during years of decline in prey abundance in several populations (Douglas et al. 1987, Thompson and Colgan 1987). Flynn and Schumacher (2009) found that similar to other marten populations across North America, marten abundance on northeast Chichagof Island in Southeast Alaska fluctuated in response to long-tailed vole (*Microtus longicaudus*) abundance.

Multiple studies have also shown that marten broaden their diets when availability of preferred prey declines (Thompson and Colgan 1990). On Chichagof Island *M. americana* consumed the seasonally available salmon (*Oncorhynchus* sp.) in summer and fall and Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) carcasses in winter during years when vole abundance declined (Ben-David et al. 1997). On the Queen Charlotte Islands, British Columbia, Canada, where voles are absent, *M. caurina* exhibited a diverse diet in winter with the lowest incidence of small mammal prey reported for any western North America population (Nagorsen et al. 1991). These authors also noted that Sitka black-tailed deer and salmonids were important food resources for these animals (Nagorsen et al. 1991). Pacific martens on Vancouver Island, where small mammals occur in low abundance and the only vole species is restricted to limited patches of available habitat, were also found to eat a varied diet with low incidence of voles (Nagorsen et al. 1991). Nagorsen et al. (1991) noted that martens on Vancouver Island exploited four introduced species rather than consuming Keen's mice, which were abundant, and that passerines composed an important portion of the diet along with seasonally available salmon (Nagorsen et al. 1991). This flexibility in prey-switching and distribution of alternative prey across the landscape may influence habitat selection of marten in an unpredictable manner.

The long term study (2007 – 2012) by the Alaska Department of Fish and Game (ADF&G) exploring the effects of timber harvest on the dynamics of this population (Flynn et al. 2012), provided an opportunity to evaluate the effects of demography on habitat selection of martens given temporal fluctuations in prey availability. Our objectives were to 1) determine marten habitat selection in terms of landcover types and landscape features , 2) investigate how prey availability affects habitat selection and landscape distribution of martens on Kuiu Island, and 3) investigate effects of population demographics on resource selection. We hypothesized that when marten densities are high, individuals would select lower quality habitats compared with years when densities were lower. We also hypothesized that subordinate juvenile individuals would select lower quality habitats than adults. Finally, we hypothesized that juveniles would consume lower quality foods (e.g. salmon) than adults, and adult females would feed on higher quality food (terrestrial meat) due to the nutritional demands of reproduction.

Study Area

Kuiu Island is the 7th largest (196,200 ha) in the Alexander Archipelago, Southeast Alaska, and falls within the Tongass National Forest (TNF) about 75 km west of Petersburg (56°28’N, 134°1’W). Due to its coastal location, Kuiu has a maritime climate consisting of cool (12.65 ± 0.4 °C) and wet (2,774 mm) summers, and cold (1.49 ± 0.2 °C) winters with deep snow (1,956 mm). Lower elevations (below 1,000 m) are snow free from early May to November. Higher elevations, where snow persists longer, are typically covered in alpine tundra. The study area (Figure 1) consists of a mosaic of habitats including muskeg and grassy meadows, old-growth coniferous forest, clear-cut logged stands, even aged pre-commercially thinned stands, and a dense network of streams with associated riparian habitat. The dominant overstory in coniferous forested stands is Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*). The dominant understory in those stands consists of devil's club (*Oplopanax horridum*), blueberries (*Vaccinium* spp.), false azalea (*Menziesia ferruginea*), and salmonberries (*Rubus spectabilis*; Flynn et al. 2012).

Because we were interested in the effects of forest management practices on marten we chose northern Kuiu Island for our study area. Since 1929, 8,863 ha of old-growth forest stands on Kuiu Island have been commercially clear-cut with the majority of logging occurring between

1970 and 1990. Prior to our study the most recent clear-cut logging occurred in 2000. Forest management practices on the TNF prescribe pre-commercial thinning within ~25 years post clear-cutting. Of the 55,000 ha (550 km^2) study area 16% were clear-cut prior to 2000, with 54% of stands subsequently thinned with a 3.0 to 4.9 m (most common) spacing among the regenerating trees. In total 1,140 ha were thinned during 2010 and 2011. Thinning for fish and wildlife habitat improvements composed less than 50 ha.

Potential diet items that were available to martens during our study include red squirrels (*Tamiasciurus hudsonicus*), long-tailed voles, Keen's mice, and sooty grouse (*Dendragapus fuliginosus*). Carcasses of pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*) were available in the late summer through late fall. Blueberries (*Vaccinium ovalifolium*) and huckleberries (*V. alaskensis*) were seasonally available, largely in late-summer and early-fall. Sitka black-tailed deer and moose (*Alces alces andersoni*) are found on Kuiu in very low densities and could be available as carcass remains from black bear (*Ursus americanus*) and wolf (*Canus lupus*) predation. However, because of their low densities they are unlikely to be a commonly-encountered food item. Although intertidal marine organisms are available to martens, they are rarely consumed elsewhere in Southeast Alaska (Ben-David et al. 1997).

Methods

Trapping and tracking martens

In 2007–2012, we live captured martens along 3 traplines (115 trap sites) using logging roads (Flynn and Schumacher 2009). In 2012 we added 2 traplines for a total of 152 trap sites. Single traps (Model 203, Tomahawk Live Trap Co., Tomahawk, WI) were set approximately 500 m apart along each transect and baited with strawberry jam, sardines, or venison scraps and placed under logs or the base of trees within 50 m of the road. A commercial marten lure (S. Stanley Hawbaker & Sons, Fort Loudon, PA) was used as olfactory attractant at each trap site. To ensure animals did not experience discomfort or suffer from hypothermia we covered the traps with tarp and checked them daily.

The length of the trapping period varied by year, but typically lasted from mid-September to late-October. We sedated captured martens with an injection of a mixture of 18.0 mg/kg ketamine hydrochloride (Ketaset, Fort Dodge Animal Health, Fort Dodge, IA) and 1.6 mg/kg xylazine hydrochloride (The Butler Company, Columbus, OH). All captured martens were ear tagged (Size 1, Style 1005, National Band and Tag Co., Newport, KY), sexed, weighed (to the nearest 1g), and measured (total, body, and tail length to the nearest 1 cm). We extracted the first two premolars (upper or lower) for age determination by analysis of cementum annuli (Matson's Laboratory, Milltown, MT), and grouped martens into juveniles (cementum age = 0) and adult (cementum ≥1) classes. Martens recaptured during the same trapping session were released without additional processing.

Martens in good condition (*n* = 126) were fitted with radiocollars. Female martens were collared with 35 g transmitters with a life-expectancy of 12 months (Telonics MOD-073, Telonics, Mesa, AZ). To males, we attached a 49-g collar (Telonics MOD-080) with an expected life of 12-18 months. We located radio collared martens from small aircraft during daylight hours at bi-weekly to monthly intervals throughout the year depending on weather conditions. The location of each animal was verified by circling the aircraft (Mech 1983) and recorded using a global positioning system (GPS) technology. Using known transmitter locations we determined the error at 105 ± 33 m (*n* = 15). We entered all locations into geographic information system (GIS) using ArcGIS 10 software (ESRI, Redlands, CA) and rated the quality of the data from poor to excellent based on observer experience and radio signal strength. All spatial analyses were completed using the same GIS software and program R (R Core Team 2014), after exclusion of suspect data (i.e., rated poor by the observer).

Estimating marten demographic parameters

Because in several years of the study the number of recaptures was too low for producing reliable abundance estimates, we derived the following demographic metrics: 1. minimum number known alive (MNKA), which was the sum of all captured individuals during a trapping session (Graipel et al. 2014); 2. capture success computed as the number captured per 100 trap nights (Flynn and Schumacher 2009); 3. percent juveniles, calculated as the number of juveniles divided by the number captured times 100; and 4). ratio of juveniles to adult females in the sample (Lee et al. 2005). Because most of the captured animals were hybrids (R. W. Flynn, *unpublished data*) we did not attempt to derive species-specific metrics.

Small mammal sampling

We used museum special snap-traps to obtain an index of small mammal abundance by placing two traps in each station located every 15 m along 350 m transects. We baited the traps with peanut butter and rolled oats (Flynn and Schumacher 2009). Traps were set for three consecutive nights (Calhoun 1948, Southern 1965). We placed traps along six transects: two were in high volume old-growth forest dominated by spruce and hemlock, two were in mixed conifer medium volume old-growth forest, one trapline was set in meadow habitat, and one in riparian habitat dominated by spruce. We operated all six transects for a total of 150 trap nights every fall from 2007-2012. We expressed the results using the index number of captures per 100 trap-nights. All mortalities were collected for stable isotope analyses.

In 2012 we expanded this effort and used concurrent live trapping to assess the relationship between small mammal abundance derived from live captures (captures per 100 trap-nights) and that obtained from snap trapping. Live trapping was conducted in six grids consisting of 36-45 Sherman traps baited with peanut butter and rolled oats and set in 4 or 5 x 9 configurations at 25 m distance. Four grids were placed in high volume, old-growth stands and two in thinned stands. Small mammals were marked with a Passive Integrated Transponder and released at site of capture. We compared results from live-capture estimates to the snap trap index using correlation.

All capture and handling procedures were approved by the Animal Care and Use Committee of the Alaska Department of Fish and Game and were consistent with the animal care guidelines of the American Society of Mammalogists (Sikes and Gannon 2011). Carcasses and tissue samples were collected under ADF&G collecting permit # 07-118.

Tissue sampling for diet analyses

From each live-trapped marten we collected guard hairs from the torso (n = 152 samples from 120 individuals). All hair samples were stored frozen and then prepared at the University of Wyoming for stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analyses using standard procedures (Ben-David and Flaherty 2012). Hair samples were rinsed three times with 2:1 chloroform: methanol solution and were placed in a drying oven at 60°C for 3 days and then homogenized with scissors. We weighed a subsample in tin cups and submitted them to the University of Wyoming Stable Isotope Facility in duplicate. Samples were analyzed for $\delta^{13}C$ and $\delta^{15}N$ using a Costech 4010 elemental analyzer (Costech Analytical, Valencia, CA) attached to a Delta^{PLUS} XP Continuous Flow Isotope Ratio Mass Spectrometer (Thermo Scientific, Finnegan; http://www.thermoscientific.com/en/products/isotope-ratio-mass-spectrometry-ir-ms.html).

To determine the dietary contributions of various foods we excised 1 g of muscle tissue from carcasses of pink salmon (*n* = 5), chum salmon (*n* = 5), sooty grouse (*n* = 6), voles (*n* = 10) and Keen's mice (*n* = 236) collected on Kuiu Island. In addition, samples of blueberries (*n* = 25) and huckleberries (*n* = 22) were gathered after they ripened in the fall. These samples were analyzed for $\delta^{13}C$ and $\delta^{15}N$ using the same above techniques. Because we were unable to obtain coho salmon samples during our field season on Kuiu Island we used values for coho salmon from a previous study on northeast Chichagof Island (Ben-David et al. 1997). Also in order to increase our sample size for grouse we used isotope values from samples (*n* = 6) collected in Juneau, Alaska (R. Flynn, ADF&G, *unpublished data*).

Resource selection modeling:

We investigated habitat selection at the population level and study area scale (550 km^2) by comparing site characteristics of used locations (*n* = 1,115; coded 1) to those of random available points (51/km^2 for a total of 28,203; coded 0) using logistic regression (resource selection functions; RSFs) as implemented in the glm function in program R (R Core Team 2014). We defined the available study area boundary by creating a 4.5 km buffer around each marten capture location and then dissolving all buffers into one contiguous polygon.

To quantify habitat variables within the study area boundary, we used digital elevation models and Geographic Information System (GIS) layers obtained from the Southeast Alaska GIS library for each 30 m^2 raster cell. These included the vegetation cover type (Size Density 2013), USFS Class I stream layer (AK Hydro Streams in Southeast, Alaska), and United States Geological Survey (USGS) Interferometric Synthetic Aperture Radar (IfSAR) Digital Surface Model (DSM), and IfSAR Digital Terrain Model (DTM) raster data (Dewberry 2015). In addition, we developed rasters with values for quadratic mean diameter (QMD) and stand density index (SDI), which are based on measurements of density at breast height (DBH) and stem density. QMD and SDI are often used as indicators of forest structure (Caouette and DeGayner 2008). These values were compiled from stratified random vegetation sampling plots within our small mammal sampling grids as well as from data collected by R. W. Flynn in several locations in Southeast Alaska (R. W. Flynn, *unpublished data*) and from a companion study on Prince of Wales Island (Eckrich et al. 2013).

We chose elevation, SDI, QMD, distance to shore, stream density (within a 500m buffer around 30 m^2 cell) and IfSAR.diff (the difference between the IfSAR-DSM and the IfSAR-DTM; an index of forest canopy structure) as predictive variables (Table 1). To relate values of IfSAR.diff to timber volume classes used in to USFS TNF Size Density Model we calculated the mean and standard deviation (SD) of IfSAR.diff for each volume class (Table 2). Because the geometry and canopy density are the most influential factors on IfSAR.diff, this metric can be a good index of forest canopy structure (Anderson et al. 2006). Anderson et al. (2006) suggested that acquiring data from multiple-look directions would significantly improve accuracy. The IfSAR dataset we used was derived from multiple-look angles incorporating both X-band and P-band collection procedures and accepted by the USGS only after a thorough quality assurance process (Dewberry 2015). We further investigated the performance of IfSAR.diff as an index of forest canopy height and structure by comparing its values with QMD and SDI measurements obtained from our small mammal sampling grids (Table 3). Finally, because the IfSAR has a 5 m resolution we resampled the rasters to convert the data to 30 m^2 cell sizes and confirmed all rasters were the same extent, origin and projection prior to analyses.

As a first step in the analyses, we evaluated the existence of multi-collinearity and included only variables that had an *r*-value < |0.6| in RSF models (Tabachnick and Fidell 1996, Hosmer Jr. and Lemeshow 2004). Thus, because elevation was correlated with stream density (*r* = -0.6) and SDI was correlated with QMD (*r* = 0.81) we excluded these variables from our models. Second, because telemetry error was larger than the habitat cell size, we used the focal function in the raster package (R Core Team 2014) to calculate the mean values inside a 150 × 150 m moving window (Shirk et al. 2014) for every cell in each raster. Similar to other studies in Southeast Alaska (Flynn and Schumacher 2004), few marten locations (*n* = 15) occurred above 457 m (1500 ft.). Therefore, we removed all used and random available locations above 457 m to eliminate the potential effect of excessive number of unused locations above this elevation. Third, because the units of measurement of continuous habitat variables were of different scales, all were standardized by calculating their z-scores. After this data was processed we extracted the values for location data using program R (R Core Team 2014). We constructed a set of candidate models and evaluated data fit using Akaike's Information Criterion (AIC; (Burnham and Anderson 2002), area under the curve (AUC) and significance of variables (Hosmer Jr. and Lemeshow 2004) using program R (R Core Team 2014). We also evaluated the top RSF model for predictive performance by k-fold cross-validation methods (Boyce et al. 2002). For each fold (k = 5) we selected 80% of the data as the training set and binned the RSF model results into 10 equal area bins. We repeated the process with the withheld data (remaining 20%).We evaluated the predictive performance of the model by comparing the expected (training set) binned values vs. observed (withheld) binned values using Spearman-rank correlation (Boyce et al. 2002). We then created a predictive surface map representing marten selection by multiplying model coefficients (β) of each variable by the raw values in each 30 m^2 cell, summing the values for each cell and deriving the exponent using the raster package in R (R Core Team 2014). In this predictive map, each pixel reflects an RSF score proportional to the probability of use by martens (Boyce et al. 2002).

To examine effects of marten demography and season (i.e., timing of salmon availability) on resource selection we developed Latent Selection Difference (LSD) functions (Mueller et al. 2004, Fischer and Gates 2005, Latham et al. 2011). LSD functions differ from RSFs in that the availability is held constant and the response values of two groups (e.g., adult and juveniles) are coded as zero or one. Because availability is held constant in LSD models, they must be interpreted as the relative difference in selection between the two groups and do not represent the actual selection for any particular explanatory variable (Latham et al. 2011). We used variables identified as influential in the top RSF model for developing the LSDs.

To investigate selection difference between age classes we divided marten locations into two categories: adult locations (n =876) coded as 0 and juvenile locations (n = 239) coded as 1. In this analysis we pooled male locations (n = 706) and females location (n = 409). We then explored the effect of sex (by coding locations from females as 1 and locations from males as 0) while pooling across ages. Because of the changes in availability of salmon, which spawn on Kuiu Island in late summer and fall, we investigated seasonal differences in habitat selection by coding winter/spring (January 1 - May15) locations as 1 and summer/fall (May 16 - December 31) locations as 0. For this analysis all age and sex classes were combined. Finally, we evaluated the effects of marten abundance and the ratio of juveniles to adult females (juv/adult female) on habitat selection. Since 2011 had the highest captures/ 100 trap nights, the highest MNKA and the highest proportion of juveniles in the population we coded locations from martens collected in 2011 as 1 and locations from all other years as 0 (average and below average years combined). All age and sex classes were combined for the marten abundance LSD.

Estimating diet composition

To assess the effects of age class, sex, and demography on marten diet we used a multivariate analysis of variance (MANOVA) with $\delta^{13}C$ and $\delta^{15}N$ in marten hair as the dependent variables and sex and year as the independent variables. We also analyzed the isotope data with age class as a dependent variable because of the large fluctuations in the number of juveniles among years. To further explore differences among categories, we followed the MNOVA with a Welch's two sample t-tests, comparing adult females to other age and sex classes. We estimated the relative contribution of each food assimilated into marten guard hairs using Bayesian stable-isotope mixing-models (Phillips 2012). Bayesian stable-isotope mixing-models require that all sources in the model be significantly different from each other in $\delta^{13}C$ and $\delta^{15}N$ or sources must be combined *a priori* (Phillips et al. 2005). We used a K nearest-neighbors randomization test (KNN) for differences between sources (Rosing et al. 1998) after correcting $\delta^{13}C$ values for hair by -1‰ (Darimont and Reimchen 2002). Sources that were not significantly ($p > 0.05$) different from each other (pink and chum salmon and berries species) were combined into two groups. However, because we were interested in total biomass of salmon consumed by martens we combined all salmon species *posteriori* (Phillips et al. 2005).

In the first set of models we included all possible diet items. However, because berries contributed less than 1% of consumed biomass we re-ran the models with berries excluded. Also, the distribution of end members and the resulting mixing space may mask the relative contribution of sources that occur inside the hull (Keen's mice and voles). Therefore, we also ran the mixing models without grouse and compared the resulting consumption estimates. We conducted these diet contribution analyses with the MixSIAR GUI (Stock and Semmens 2013) for program R (R Core team version 2014). We used the default setting in MixSIAR which include process error (propagation of the estimated uncertainty in the source and discrimination values), residual error (which accounts for additional unknown sources of error apart from discrimination and source values), and concentration dependence for source values in the model. We used $\delta^{13}C$ = 1 (±0.35; SE) and $\delta^{15}N$ = 3 (±0.65) as discrimination values for salmon and $\delta^{13}C$ = 2 (±0.35) and $\delta^{15}N$ = 3 (±0.65) for all other potential sources (Ben-David et al. 1997b). For concentrations we used %C = 0.50 and %N = 0.15 for salmon, 0.49 and 0.13 for mice and voles, 0.49 and 0.02 for berries, 0.49 and 0.14 for grouse, and for red squirrels we used %C = 0.49 and %N = 0.15. We ran the MCMC simulations in MixSIAR using customized settings of chain length = 3,000,000, burn in = 2,700,000, and thin = 300 for 3 separate chains. We checked trace plots and Gelman-Rubin and Heidelberger and Welch diagnostic tests in order to confirm that the MCMC chains converged on feasible solutions.

Results

Marten demography

We captured 159 martens during the study of which 21 individuals were captured in more than one year (Flynn et al. 2012). During the first three years (2007–2009), MNKA was below the six year mean for the population (30 individuals; Table 4). From 2010–2012, MNKA was above the six year population mean due to an increase in juveniles in 2010 and 2011 (Table 4). In 2010, the percent juveniles in the sample increased by 32% compared with the six year mean (38. 9%) and in 2011 it was 61% higher than the six year mean. Although in 2012 we captured the second highest number of martens (37), the percent of juveniles in the population dropped by 52% to 29.7% (Table 4). The number of juveniles per adult female in 2010 and 2011 were 54% and 115% greater than the 6 year mean of 1.57 (Table 4).

Small mammal sampling

The study area-wide number of Keen's mice captured/100 trap nights fluctuated annually from a low of 1.7 in 2007, to a high of 9.6 in 2011 (Figure 2). The six year overall mean was 6.6 captures /100 trap nights. In contrast, vole abundance remained chronically low throughout all years ranging from none captured in 2008, 2011, and 2012 to 0.2 in 2010. We captured the highest numbers of Keens mice Keen's mice in high volume old-growth forest, mixed conifer, and old growth hemlock stands. Keen's mice abundance in riparian and meadow habitats was ~ 50% lower than in the forested stands. During snap trapping we caught only 4 voles in two years in mixed conifer stands, 1 in meadow habitat, and 1 in a spruce riparian stand. No voles were captured in high volume old-growth stands.

Small mammal abundance estimates in fall 2012 ranged from 8 to 24 per 100 trap nights in the high-volume stands and from 2 to 10 per 100 trap nights in the thinned stands. These values were highly correlated with snap-trap captures ($r = 0.96$, $P = 0.01$).

Marten habitat selection

The top resource selection model contained 3 parameters, explained the most residual deviance, had the lowest AICc score and was the most parsimonious of the 13 models we constructed to assess resource selection by martens (Table 5). Additional parameters in all other models were uninformative (Burnham and Anderson 2002, Arnold 2010). Although AUC estimates were identical for the top 2 models (0.70), model 2 was more parsimonious. Also, all parameter *p*-values in model 2 were significant (Table 5). The rho values for all five folds cross validation models were high with a mean of 0.90, $P < 0.001$. All χ^2 tests had $P > 0.1$ and no *y*-intercepts were significantly different from 0 and no slopes were significantly different from 1, indicating that our top overall model performed well (Wiens et al. 2008).

In the top model, distance from shore had the largest coefficient (negative) suggesting strong selection against habitat further from the coast (Table 6). In addition, stream density and IfSAR.diff both exhibited positive coefficients suggestive of selection for them by martens. The RSF surface map (Figure 3) illustrates that marten are predicted to occur near streams and/or the coastal regions in higher volume closed-canopy forest (i.e. stands with higher IfSAR.diff values).

LSD functions (Appendix A) suggest that juvenile martens were 13% more likely to select for stream density and 15.9% less likely to select for IfSAR.diff relative to adults. Similarly, LSD functions suggested that females were 6.5% less likely to select for stream density and 25.8% more likely to be found further from the shore than males.

In 2011, when MNKA and captures/100 trap nights were highest, we estimated that all martens were 17.8% more likely to select for stream density than during all the other years combined. Also during 2011, adult females were 16% more likely to select for stream density and 56.9% less likely to select for distance from shore than during all other years combined. Finally, we found that martens were 12% less likely to select for stream density during the winter and spring seasons than during summer and fall (Appendix A).

Estimated diet composition

Stable isotope analysis of hair collected from martens (during fall) showed that overall martens on Kuiu Island were enriched in δ^{13}C and δ^{15}N, indicating a strong marine signature (Figure 4). The MANOVA model was highly significant (δ^{13}C: $F_{18, 133} = 2.74$, $P = 0.001$; δ^{15}N: $F_{18, 133} = 3.66$, $P < 0.001$), with strong year (δ^{13}C and δ^{15}N: $P < 0.001$) and sex (δ^{13}C: $P = 0.017$; δ^{15}N: $P = 0.003$) effects. The interaction between sex and year was not significant (δ^{13}C: $P = 0.355$; δ^{15}N: $P = 0.510$). The effect of age in the overall model was marginal (δ^{13}C: $P = 0.074$; δ^{15}N: $P = 0.104$). Nonetheless, a model with age as the sole predictor was significant (δ^{13}C: $F_{1,150} = 4.18$, P

= 0.043; δ^{15}N: $F_{1,150}$ = 6.62, P = 0.011). Overall, juveniles were more enriched in δ^{13}C by 0.37‰ and δ^{15}N by 0.78‰ than adults, and males were more enriched in both δ^{13}C by 0.46‰ and δ^{15}N by 0.79‰ (Table 7). A follow up t-test showed that adult females were depleted in δ^{15}N relative to other age and sex classes ($p < 0.001$).The overall mean δ^{15}N for the population in 2011 was 12.8‰ and 1.5‰ higher than the five year average (Table 7).

The mean estimates of consumed salmon biomass from the Bayesian mixing models when grouse were excluded from analyses ranged from a low of 55% in 2010 to 84% in 2011 (Table 8). In contrast, the estimates for vole biomass in these models ranged from 3% in 2011 to 16% in 2012 which is consistent with the chronically low abundance index estimates. Surprisingly, Keen’s mice estimates ranged from 7% in 2011 when their abundance indices where at six year high to 23% when they were at moderate levels. The contribution of red squirrels ranged from 4% to 11% (Table 8). When we included grouse in the models but excluded berries, consumption of this prey item ranged from 6% to 22% of the diet and the proportion of Keens mice and voles decreased to under 8% for all years. There was little effect of grouse inclusion on the estimates of salmon contributions; their percent remained high ranging from 61% to 86% in 2011 (Table 8).

We found no positive correlation between the abundance of Keen’s mice and their consumed biomass estimates whether we included grouse and berries or excluded them from the models, suggesting that martens on Kuiu Island shift primarily to seasonally available salmon regardless of Keen’s mice population levels. Nonetheless, the availability of Keen’s mice in 2011 was only 33% higher relative to 2010 compared with the increase in number of juvenile martens in the population (59%). Similarly, Keen’s mice indices declined by 30% from 2011 to 2012 concurrent with a 59% decrease in proportion of juveniles. These inconsistent trends may explain some of the observed dietary patterns because juvenile martens consistently consumed more salmon than adults.

Discussion

Our analyses showed that demography played an important role in selection of resources by martens on Kuiu Island. In general, martens on northern Kuiu Island selected for higher volume, closed-canopy forest (as reflected by the IfSAR.diff data), in proximity to the coastline and salmon streams. Both stream density and distance from shore exhibited coefficients larger than the index of canopy structure (IfSAR diff) potentially representing the importance of marine food resources. Habitat selection, however, differed among age and sex classes with adult females consistently using locations that were further from shore and lower in stream density than other martens (especially juveniles). Adult females also consistently were the most depleted in $\delta^{15}N$ relative to adult males and juveniles. In contrast, juveniles occurred in areas with a higher density of salmon streams and a showed lower preference for higher volume closed-canopy forest than adults. Juveniles were also the most enriched in $\delta^{15}N$ suggesting high consumption of salmon. These effects of demography on resource selection were especially apparent during 2011 when high number of juveniles resulted in changes in diet and habitat selection for all individuals. In fact, estimated salmon biomass consumption during 2011 was greater than any other estimate noted Southeast Alaska by a minimum of 22% (Ben-David et al. 1997, Flynn et al. 2004).

The high consumption of salmon by Kuiu martens compared to other locations in Southeast Alaska was unexpected. A dense network of salmon streams provides ample access to this seasonally abundant food resource which occurs mid-July through late November and likely persists preserved by cold temperatures underneath snow into late winter or early spring. However, Ben-David et al. (1997) found that *M. americana* on northeast Chichagof Island consumed more salmon during years of low small mammal abundance but that most martens consumed voles in higher proportion than available. These authors suggested that martens may be incapable of fully digesting and assimilating salmon lipids (Ben-David et al. 1997). This may explain the lower consumption of salmon by adult females. It is possible that due to the demands of reproduction, adult females may have a physiological drive to seek alternative food resources when they are available in adequate quantities. If so, the decline in the proportion of juveniles in 2012 could have resulted from the increased consumption of salmon by adult females in 2011. This hypothesis requires further investigation.

The relative contribution of grouse to marten diets on Kuiu could have been a modeling artifact or actually represent true consumption of this resource. Although we did not estimate grouse abundance they were seen nearly daily along logging roads in June through late October by ADF&G and USFS personnel indicating that grouse likely occur at moderate densities on Kuiu Island. Nagorsen et al. (1991) found that on the Queen Charlotte Islands, small birds in winter diets were a substitute for small mammals, suggesting that avian prey may be important for insular populations. However, similar to grouse, red squirrels were also commonly seen, yet their estimates were considerably lower. Thus it is possible that the distribution of the data in isospace influenced results from mixing models (Phillips et al. 2014). The distribution of sources in isospace has been known to affect mixing model results (Phillips and Gregg 2003). Also, the choice of discrimination values, which exhibit considerable variation due to environmental and physiological factors (McCutchan et al. 2003, Wolf et al. 2015, Yeakel et al. 2016), could influence the results of the mixing models. Although these limitations of mixing model potentially confounded our ability to estimate the proportion of grouse and small mammals simultaneously we believe that grouse and Keen’s mice are likely both utilized by martens on Kuiu Island given their abundance and the lack of voles.

In most years, the high consumption of salmon was largely a function of the proportion of juveniles in the population. This behavior strongly influenced habitat selection. We hypothesized that similar to Keens mice on Prince of Wales Island (van Horn 1980), juvenile martens would use lower quality resources due to their subordinate status and inexperience on the landscape. Indeed, although juveniles selected for high density of salmon streams, they were less likely to occur in closed-canopy stands than adults. These results are not unique to our study. For example, Wolff et al. (2015) found that site occupancy by American mink (*Neovison vison*) in summer was related to presence of “hot spots” of high prey abundance (Wolff et al. 2015). Similarly, Fukui et al. (2006) found that emerging aquatic insects was a strong driver on choice of foraging habitat for bats. Similarly lynx (*Lynx canadensis*) and coyotes (*Canis latrans*) were shown to modify habitat selection based on availability of snowshoe hares (O'Donoghue et al. 1998)and finally, Larter and Gates (1991) found that wood bison shifted their use of habitats based on seasonally available food patterns. Indeed marten on Kuiu Island exhibit strong fidelity to salmon streams and selection for this abundant resource. However, we have shown that diet selection and demography combined can alter resource selection beyond the simple effects of food availability. The influence of demography on resource selection in other species and in other study systems warrants future investigations.

The influence of prey availability and demography on habitat selection patterns by martens on Kuiu Island constrains the overall population habitat use to a fraction of this fragmented landscape. This distribution on the landscape is reminiscent of patterns observed by

Fisher et al. (2012) in Alberta, Canada, where American martens and fishers (*M. pennanti*) co-occur. In that study, martens and fishers selected different habitat features and responded differently to fragmentation (Fisher et al. 2012). Nonetheless, martens were absent from fractions of suitable habitats on the landscape as a result of occupancy by fishers. These authors concluded that in order to truly understand how species co-exist, habitat selection theory should be integrated with population level processes (Fisher et al. 2012). Indeed, our results further support this assertion and suggest that similar consideration should be given to intra-specific processes.

In one of the few formal assessments of habitat selection by martens, Shirk et al. (2014) have shown that site specific availability of habitats on the landscape determine the distribution of martens. In that study, martens selected riparian habitats in the mesic site (Washington) but were sensitive to canopy cover and forest fragmentation in the xeric site (Oregon). The authors concluded that habitat selection by martens can be site specific and that this factor should be considered when developing forest management plans with martens as indicator species (Shirk et al. 2014). Here we demonstrate that additional factors especially demography should be considered for marten management and conservation on Kuiu Island.

Management Implications

The low abundance of small mammals (especially voles), limited availability of high volume forest and the spatial constraints due to minimal use of higher elevations and high affinity to salmon streams and the coast, suggests the viability of the marten population on Kuiu Island would be negatively impacted by further timber harvest. High fidelity to lower elevation sites would also likely increase vulnerability to trapping harvest along road corridors. Given the frequency of occurrence of salmon in diets of marten in Southeast Alaska managers in the TNF that want to conserve marten populations should strongly consider retaining high volume forest classes especially in valley bottoms within proximity to salmon streams and the shore.

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Figure Captions

Figure 1. Left- Kuiu Island study area with black triangles representing all locations were marten were found using radio telemetry and black squares representing live capture locations. Right-Kuiu Island study area with clearcuts (harvested stands) shown in grey and pre-commercially thinned stands with cross-hatches.

Figure 2. Comparison of the number of Keen's mice (PEKE) captured per 100 trap nights (TN) and the number of martens per 100 TN.

Figure 3. Predictive map of Kuiu Island showing study area boundary with US Forest Service class I anadromous salmon spawning streams. Habitats were binned into five categories based on RSF scores, which are proportional to the probability of marten occurrence on the landscape. White indicates lowest RSF scores and darker red areas indicate highest RSF values.

Figure 4. Values of $\delta^{13}C$ and $\delta^{15}N$ of individual martens by year (colored dots) and mean values (± SD standard deviation) of food sources (black dots and crosses) after correction for discrimination. The mixing space is delineated by the black line.

Table 1. Covariates used to model resource selection by Kuiu Island marten in Southeast, AK 2007–2012.

Variable	Definition	Data Source
Elevation	Elevation (meters)[1]	Digital elevation model (dem)
Distshore	Distance from shore (meters)[1]	ADFG
Streamden	Stream density[1,2]	ADFG
QMD	Quadratic mean diameter[1]	ADFG & USFS
SDI	Stand density index[1]	ADFG & USFS
IfSAR.diff	IfSAR DSM minus IfSAR DTM	USGS

[1] Continuous covariates were standardized using z-score values (x-mean(x))/sd(x).

[2] Density of USFS class I salmon streams within 500m^2 buffer around raster cells.

Table 2. Means of IfSAR difference (DSM-DTM) values for random available locations with proportions of of each habitat type and standard deviations. Unproductive forest, seral forest, SD4H through SD67 corresponds to USFS Size Density Model volume classes. Second growth categories have never been thinned.

Habitat variables	Proportion	Mean	SD
Open habitats[1]	0.046	2.115	3.930
Unproductive forest	0.195	3.547	3.647
Young thins[2]	0.042	3.434	2.912
Old thins[3]	0.040	6.782	3.603
Second growth cut age 0-15 years	0.007	2.318	3.217
Second growth cut age 16-25 years	0.031	1.928	2.332
Second growth cut age 26-35 years	0.022	3.183	2.879
Second growth cut age 36-45 years	0.002	5.013	3.190
Second growth cut age 47-83 years	0.010	11.74	4.331
Seral forest	0.019	7.576	4.632
SD4H	0.058	4.972	3.180
SD4N	0.035	8.474	4.646
SD4S	0.077	7.958	4.518
SD5H	0.031	6.151	4.241
SD5N	0.085	10.325	4.753
SD5S	0.163	8.602	4.372
SD67	0.136	10.008	4.597

[1] Open habitats combined all habitat types with no forest canopy (e.g., brush, open meadows, non-forested muskegs, alpine, etc.).

[2] Young thins were thinned 5-7 years prior to the study.

[3] Old thins were thinned 11+ years prior to the study.

Table 3. Stand means for quadratic mean diameter, stand density index, and Interferometric Synthetic Aperture Radar (IfSAR) difference values for selected field stands summarized by each identified plot, Kuiu Island. OG = old growth and PCT= pre-commercially thinned stands.

Plot	QMD	SDI	IfSAR[1] Mean±SD
OG1	21.9	180	9.84±2.02
OG2	19.1	304	8.53±3.43
OG3	26.7	310	8.86±0.64
OG4	30.0	280	14.84±1.62
PCT1[2]	14.2	31	1.11±0.78
PCT2[2,3]	10.4	40	3.25.±1.14
PCT3[2]	13.0	64	4.79±1.26
PCT4[2]	12.5	38	0.61±0.16

[1] Based on only the measured subplots (400m^2 vegetation sampling plots) in each stand using the 30-m pixel IfSAR raster size. Each stand contained 4 subplots with measured vegetation data.

[2] PCT 1& 4 had thinned age 7 years. PCT2 and PCT3 had thinned age 5 years.

[3] PCT2 only has values for 3 measured subplots (1 subplot contained zero trees >9in DBH).

Table 4. Population demographic measures for martens on Kuiu Island Southeast Alaska 2007–2012.

Year	MNKA	Captures[a]	SD[b]	% Juv.	Juv/ad female
2007	27	2.0	1.1	29.6	0.89
2008	17	1.0	1.1	29.4	0.71
2009	23	2.1	0.5	30.4	1.17
2010	33	2.1	1.0	51.5	2.43
2011	43	3.2	0.8	62.8	3.38
2012	37	2.1	1.4	29.7	0.85
Mean	30			38.9	1.6
Total	180*				

*159 individual martens captured. 21 martens were captured in more than one year.

[a] Overall captures per 100 trap nights.

[b] Standard deviation of captures per 100 trap nights.

Table 5. Resource selection function models including model support (AIC, ΔAICc, AICcWt.). K= number of parameters (excluding the intercept).Top model shaded grey.

No.	Model Parameters	K	AICc	Δ_AICc	AICc wt	Cum. wt	AUC	Var1	Var2	Var3	Var4
1	Streamden[1]+distshore+IfSAR+QMD	5	8615.33	0.00	0.52	0.52	0.70	<0.001	<0.001	<0.001	0.144
2	Streamden[1]+distshore+IfSAR	4	8615.50	0.16	0.48	1.00	0.70	<0.001	<0.001	<0.001	
3	Streaden[1]+IfSAR	3	8739.02	123.68	0.00	1.00	0.68	<0.001	<0.001		
4	Streamden[1]+IfSAR+QMD	4	8739.29	123.95	0.00	1.00	0.68	<0.001	0.003	0.191	
5	Streamden[1]+QMD	3	8746.24	130.91	0.00	1.00	0.68	<0.001	<0.001		
6	Streamden[1]	2	8755.89	140.55	0.00	1.00	0.69	<0.001			
7	Distshore+IfSAR	3	8946.81	331.47	0.00	1.00	0.62	<0.001	<0.001		
8	Distshore+IfSAR+QMD	4	8948.52	333.19	0.00	1.00	0.62	<0.001	<0.001	0.591	
9	Distshore+QMD	3	8966.96	351.63	0.00	1.00	0.62	<0.001	0.036		
10	Distshore	2	8969.45	354.11	0.00	1.00	0.62	<0.001			
11	IfSAR	2	9086.99	471.65	0.00	1.00	0.55	<0.001			
12	IfSAR+QMD	3	9088.38	473.05	0.00	1.00	0.55	<0.001	0.436		
13	QMD	2	9113.29	497.95	0.00	1.00	0.52	0.019			

[1] Streamden = density of stream within 500 m^2 buffer around each cell (30 m^2) of raster developed by ADF&G.

Table 6. Coefficient estimates (β) and standard errors for the top ranked RSF used to develop a RSF for marten on Kuiu Island, AK. Coefficients are standardized to allow for comparisons among them.

Variable	β	SE	z value	*p*
Streamden	0.27	0.01	19.44	<0.001
Distshore	-0.62	0.06	-10.46	<0.001
IfSAR.diff	0.11	0.03	3.57	<0.001

Table 7. Values of $\delta^{13}C$ and $\delta^{15}N$ (mean ± SE) of martens on Kuiu Island Southeast Alaska, 2008–2012.

	Females				Males				Overall			
Year and age class	$\delta^{13}C$	SE	$\delta^{15}N$	SE	$\delta^{13}C$	SE	$\delta^{15}N$	SE	$\delta^{13}C$	SE	$\delta^{15}N$	SE
2008	-21.7	0.64	9.7	1.02	-20.7	0.37	11.4	0.51	-21.0	0.35	10.8	0.53
Adults	-21.7	0.64	9.7	1.02	-21.1	0.39	11.1	0.55	-21.4	0.40	10.4	0.65
Juveniles	-	-	-	-	-20.3	0.64	11.7	0.91	-20.3	0.64	11.7	0.91
2009	-20.4	0.38	11.4	0.45	-20.1	0.37	11.8	0.44	-20.2	0.26	11.6	0.31
Adults	-21.0	0.54	10.7	0.67	-20.1	0.45	11.6	0.52	-20.5	0.35	11.1	0.41
Juveniles	-19.8	0.38	12.0	0.45	-20.1	0.55	12.1	0.60	-19.9	0.29	12.1	0.34
2010	-21.3	0.33	10.4	0.55	-21.3	0.32	10.8	0.60	-21.3	0.22	10.6	0.41
Adults	-21.5	0.24	9.7	0.63	-21.5	0.50	10.2	1.06	-21.5	0.29	10.0	0.64
Juveniles	-21.2	0.65	11.0	0.90	-21.1	0.42	11.5	0.57	-21.1	0.35	11.2	0.49
2011	-20.7	0.10	12.4	0.27	-20.2	0.10	13.2	0.17	-20.4	0.07	12.8	0.18
Adults	-20.7	0.13	12.3	0.56	-20.3	0.09	13.5	0.24	-20.5	0.10	12.9	0.33
Juveniles	-20.6	0.14	12.4	0.32	-20.2	0.16	12.9	0.22	-20.4	0.11	12.7	0.22
2012	-21.9	0.22	10.0	0.33	-20.7	0.15	11.8	0.21	-21.3	0.16	10.9	0.24
Adults	-21.7	0.20	10.1	0.32	-20.9	0.21	11.7	0.29	-21.3	0.17	10.9	0.27
Juveniles	-22.0	0.66	9.8	0.90	-20.6	0.17	11.9	0.18	-21.3	0.36	10.9	0.51
Grand average	-21.1		10.9		-20.6		11.8		-20.8		11.4	

Table 8. Estimates of biomass consumed by martens on Kuiu Island Southeast Alaska, 2008–2012. Top panels represent models without grouse, bottom panels with grouse included in the Bayesian linear mixing models.

Year	Food item									
	Salmon	SD	Grouse	SD	Red squirrels	SD	Keen’s mice	SD	Voles	SD
2008	0.550	0.172	NA	-	0.113	0.060	0.221	0.116	0.116	0.081
2009	0.655	0.229	NA	-	0.123	0.045	0.141	0.084	0.101	0.061
2010	0.562	0.115	NA	-	0.111	0.049	0.225	0.117	0.102	0.080
2011	0.846	0.213	NA	-	0.049	0.026	0.067	0.045	0.037	0.032
2012	0.595	0.073	NA	-	0.096	0.034	0.149	0.084	0.159	0.069
2008	0.609	0.171	0.214	0.081	0.053	0.042	0.078	0.066	0.046	0.042
2009	0.675	0.243	0.167	0.061	0.057	0.036	0.061	0.050	0.039	0.034
2010	0.630	0.112	0.221	0.070	0.052	0.035	0.064	0.056	0.033	0.031
2011	0.859	0.210	0.058	0.034	0.033	0.022	0.032	0.031	0.019	0.020
2012	0.645	0.070	0.210	0.053	0.034	0.023	0.061	0.044	0.049	0.036

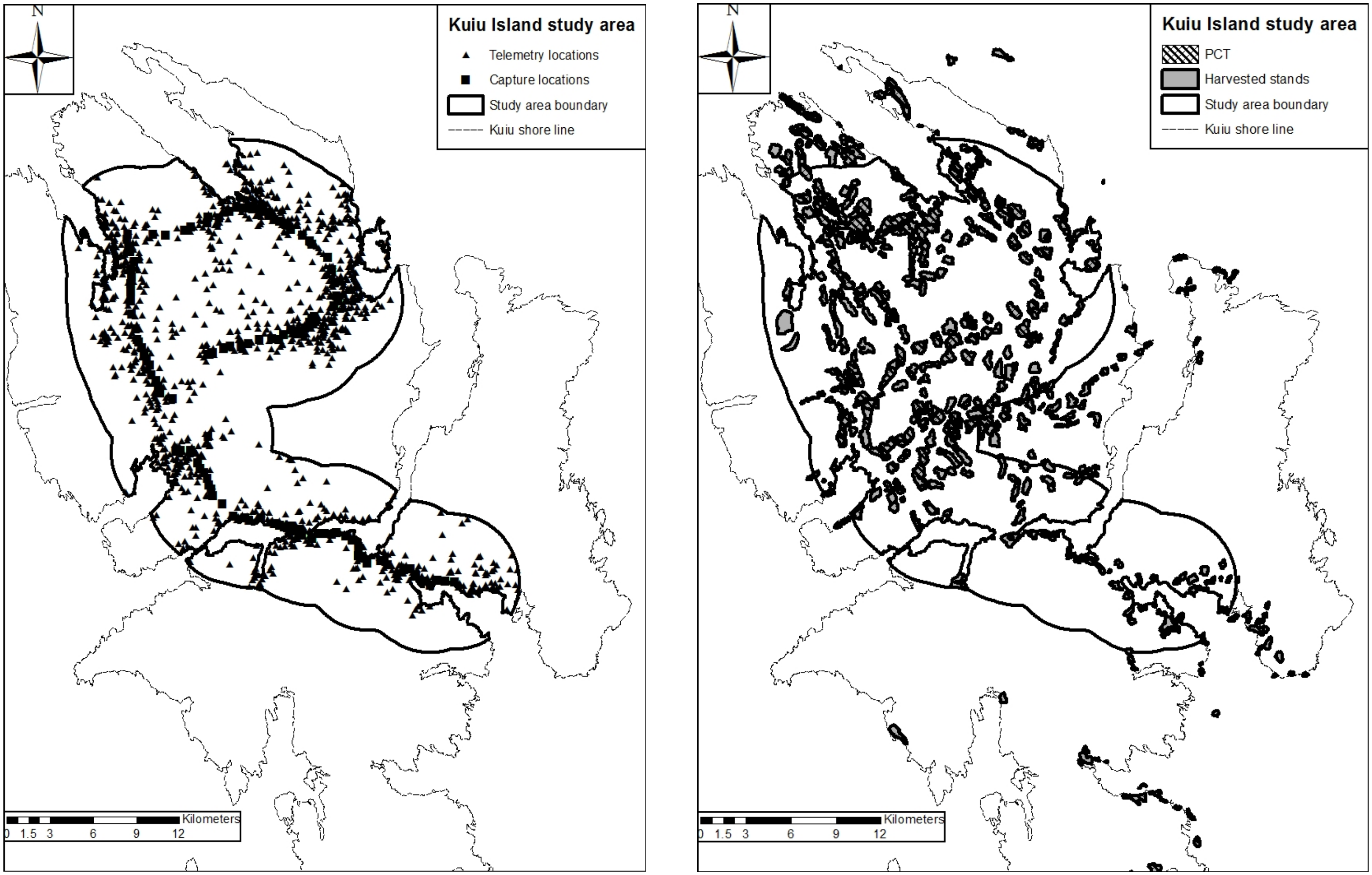
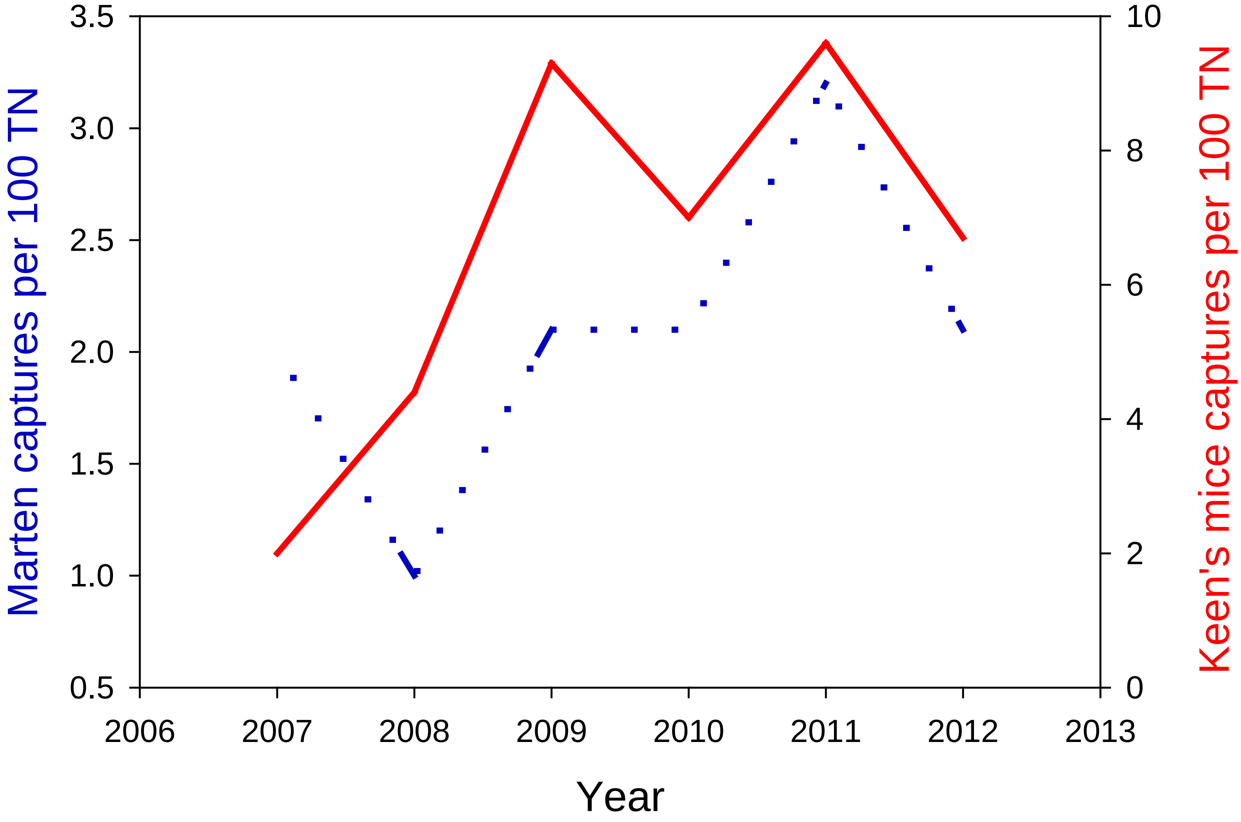

N
Kuiu Island study area
Telemetry locations
Capture locations
Study area boundary
Kuiu shore line
0 1.5 3 6 9 12
Kilometers
N
Kuiu Island study area
PCT
Harvested stands
Study area boundary
Kuiu shore line
0 1.5 3 6 9 12
Kilometers

Figure 1



3.5
3.0
2.5
2.0
1.5
1.0
0.5
Marten captures per 100 TN
10
8
6
4
2
0
Keen's mice captures per 100 TN
2006
2007
2008
2009
2010
2011
2012
2013
Year

Figure 2

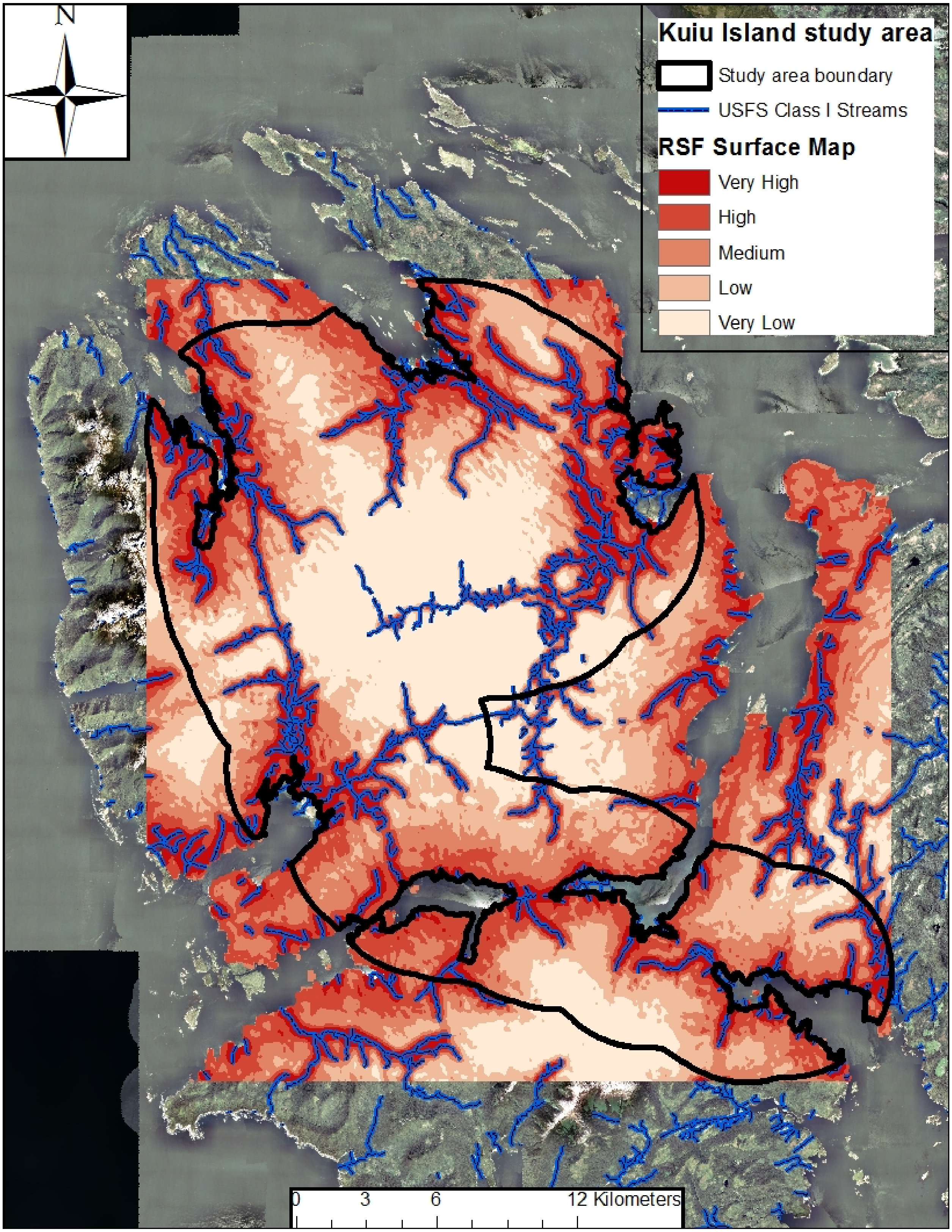
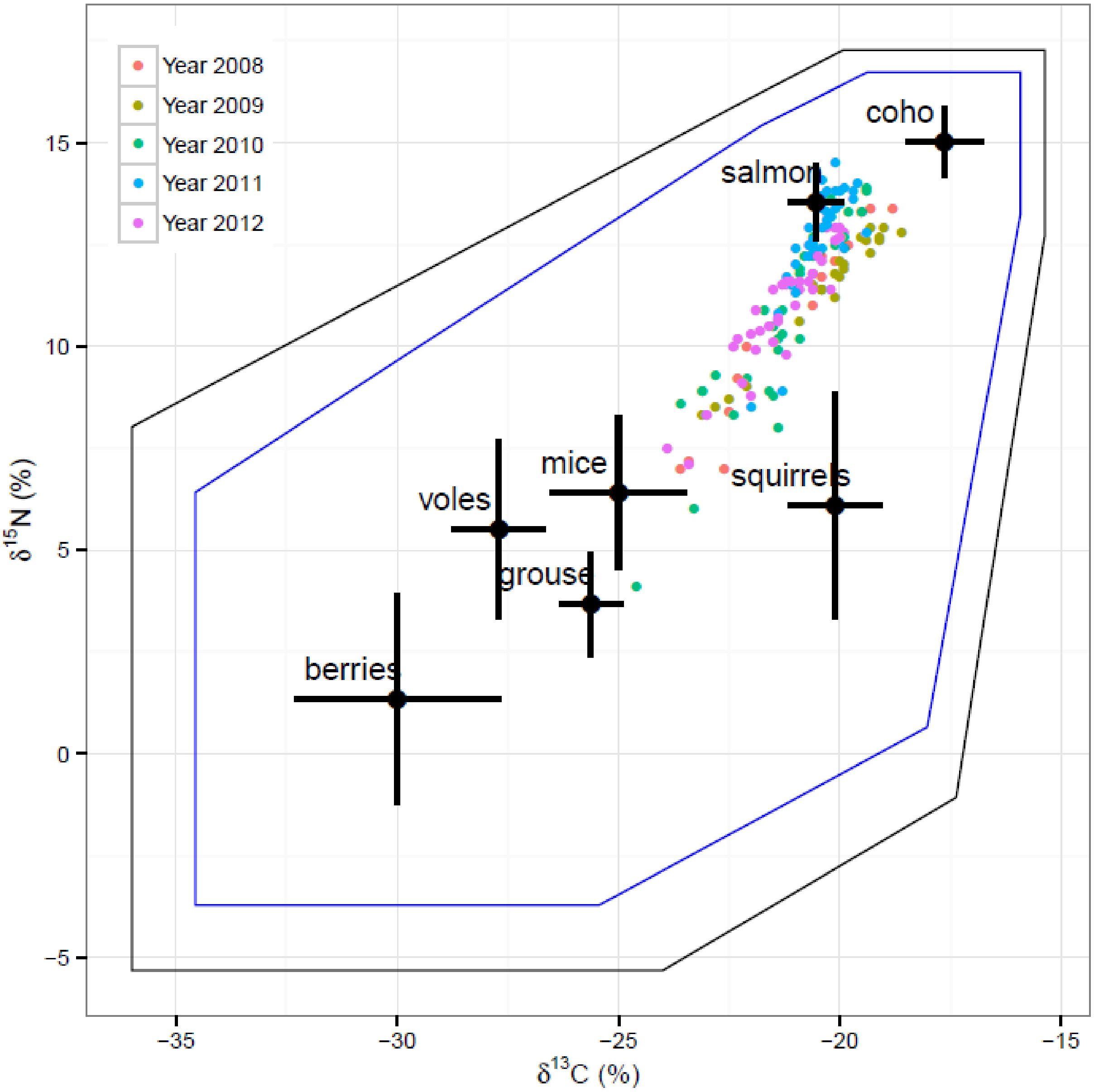

N
Kuiu Island study area
Study area boundary
USFS Class I Streams
RSF Surface Map
Very High
High
Medium
Low
Very Low
0
3
6
12 Kilometers

Figure 3



Year 2008
Year 2009
Year 2010
Year 2011
Year 2012
coho
salmon
mice
voles
squirrels
grouse
berries
15
10
5
0
−5
−35
−30
−25
−20
−15
δ15N (%)
δ13C (%)

Figure 4

Appendix A

Table A1. Coefficient estimates (β) and standard errors from latent selection difference (LSD) function comparing winter/spring (Jan 1 through May 15) coded 1 to summer/fall (May 16 through December 31) coded 0. *$P < 0.05$. Variables were standardized so that more logical comparisons can be made.

Variable	β	SE	z-value	$P > \|z\|$	Relative selection(%)[a]
Streamden	-0.13	0.03	-4.07	0.00	12%
Distshore	0.00	0.13	0.04	0.97	
IfSAR.diff	-0.47	0.63	-0.74	0.46	

[a] Relative selection obtained by using the following equation [exp(β)-1] x100. Relative selection compares the difference in selection by marten during winter/spring vs. summer/fall seasons with availability held constant. (Latham et al. 2011).

Table A2 . Coefficient estimates (β) and standard errors from latent selection difference (LSD) function coded 1 for females and 0 for males on Kuiu Island. * $P < 0.05$. Variables were standardized so that more logical comparisons can be made.

Variable	β	SE	z-value	$P > \|z\|$	Relative selection(%)[a]
Streamden	-0.07	0.03	-2.14	0.03	6.5%
Distshore	0.23	0.11	2.15	0.03	25.8%
IfSAR.diff	-0.11	0.06	-1.73	0.08	

[a] Relative selection obtained by using the following equation [exp(β)-1] x100. Relative selection is the difference in selection between selection by males and selection by females with availability held constant (Latham et al. 2011).

Table A3. Coefficient estimates (β) and standard errors from latent selection difference (LSD) function coded 1 juveniles and 0 for adults on Kuiu Island. * $P < 0.05$. Variables were standardized so that more logical comparisons can be made.

Variable	β	SE	z-value	$P > \|z\|$	Relative selection(%)[a]
Streamden	0.13	0.04	3.68	0.00	13.9%
Distshore	-0.25	0.14	-1.86	0.06	
IfSAR.diff	-0.17	0.08	-2.28	0.02	15.9%

[a] Relative selection obtained by using the following equation [exp(β)-1] x100.Relative selection is the difference in selection by marten during winter/spring vs. selection during summer/fall with availability held constant (Latham et al. 2011).

Table A4. Coefficient estimates (β) and standard errors from latent selection comparing all marten locations from the year with highest MNKA, highest captures/100 trap nights and highest proportion of juveniles (2011) coded 1 relative to other years combined coded 0. Variables were standardized so that more logical comparisons can be made.

Variable	β	SE	z-value	*P* > |z|	Relative selection (%)[a]
Streamden	0.16	0.03	4.81	0.00	17.8%
Distshore	-0.14	0.13	-1.07	0.28	
IfSAR.diff	-0.09	0.07	-1.28	0.20	

[a] Relative selection obtained by using the following equation [exp(β)-1] x100.Relative selection is the difference in selection by marten during winter/spring vs. summer/fall seasons. Relative selection is the difference in selection by martens during 2011 to all other years combined with availability held constant (Latham et al. 2011).

Table A5. Coefficient estimates (β) and standard errors from latent selection comparing locations from adult females in 2011 vs. adult female locations from all other years. Variables were standardized so that more logical comparisons could be ma

Variable	β	SE	z-value	*P* > |z|	Relative selection(%)[a]
Streamden	0.15	0.07	2.08	0.04	16%
Distshore	-0.84	0.31	-2.71	0.01	56.9%
IfSAR.diff	0.05	0.14	0.38	0.71	

[a] Relative selection obtained by using the following equation [exp(β)-1] x100.Relative selection is the difference in selection by adult females during 2011 compared to adult females during all other years combined with availability held constant (Latham et al. 2011).