Wildlife Research Report ADF&G/DWC/WRR–2021–1

Winter Habitat Selection by Sitka Black-tailed Deer on Chichagof Island, Southeast Alaska

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Alaska Department of Fish and Game Division of Wildlife Conservation

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Cover Photo: Sitka black-tailed deer on beach with deep snow at Mud Bay, Chichagof Island, Southeast Alaska. ©2007 ADF&G. Photo by Steve Lewis.

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Abstract

Management of harvested or sensitive species can benefit from understanding how habitat alterations affect habitat selection. Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) are an important food resource and the most sought after big game species in Southeast Alaska. However, uncertainty exists about the effects of timber harvest on deer. Most prior studies used only very high frequency (VHF) aerial radiotelemetry data for habitat selection analyses, which limited sample size, location accuracy, and temporal scope of inference. To help inform deer habitat management, from 2009 through 2013 we conducted a habitat selection study using high-resolution Global Positioning System (GPS) collar data from deer on northeast Chichagof Island, Alaska, an area with extensive previous timber harvest. Habitat selection of deer with resident (n = 8) and migratory (n = 14) movement tactics were analyzed using resource selection function (RSF) models to understand the influence of logging on deer habitat selection and to better delineate high-quality deer winter range. The top winter RSF models indicated relatively strong selection by both resident and migratory deer for lower elevation and commercially valuable productive old-growth forest, while stands regenerating from harvest were used in proportion to their availability. Our results and spatial predictions of important deer habitat can inform land-use planning by helping land managers balance commercial timber interests with deer habitat requirements.

Key words: habitat selection, logging, timber harvest, migratory, *Odocoileus hemionus sitkensis*, resource selection function, Sitka black-tailed deer, Southeast Alaska, ungulate, winter range.

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Introduction

Conservation and management efforts for harvested or sensitive species can benefit from understanding how habitat alterations may affect habitat selection and ultimately population performance (DeCesar et al. 2012; Gilbert et al. 2017, 2020). One such species in Southeast Alaska is the Sitka black-tailed deer. Sitka black-tailed deer are the most sought-after ungulate by hunters in Southeast Alaska, with an average of nearly 10,000 deer harvested each year (Alaska Department of Fish and Game [ADF&G] 2021). Deer are an important component of Alaska Native potlaches and ceremonies (Turek et al. 1998), and the most important terrestrial mammal in Southeast Alaska for subsistence use (Mazza 2003); up to 73% of households in some rural areas rely on deer as a subsistence staple (Brinkman et al. 2009). Deer are therefore both culturally and economically important to the public, and they are also an important ecological indicator for resource management due to their vulnerability to landscape-level alterations to forest habitats (Hanley 1993, Brinkman et al. 2009).

The habitat needs of the Sitka black-tailed deer are of particular forest and wildlife management concern because deer are thought to be strongly associated with old-growth forests in winter. Due to this strong association with productive old-growth habitat, they have been designated a forest management indicator species (Hanley 1993, USFS 2016) for the Tongass National Forest (TNF) by the United States Forest Service (USFS). Much of deer habitat in Southeast Alaska is managed by the USFS under the Tongass Land and Resource Management Plan (TLMP). Clearcut logging has significantly altered much of the forested habitat on the TNF and adjacent lands managed by the State of Alaska or private landowners (DellaSalla 2011, Person and Brinkman 2013). Currently, the long-term effects of clearcutting and even-aged forest management remain unclear for many wildlife species in Southeast Alaska. Harvested stands regenerate, and their value to wildlife differs over time as stand characteristics change.

While harvested stands produce abundant deer forage in the years immediately following timber harvest (Gilbert et al. 2017), this forage becomes seasonally unavailable when buried by snow in winter (White et al. 2009). Approximately 20–35 years post-harvest, the regenerating forest forms a dense even-aged canopy that shades out forage species, resulting in depauperate forage in all seasons (Alaback 1982, Hanley 1984). The USFS conducts precommercial thinning of harvested stands to reduce the density of trees and thereby increase forage species, but benefits to deer are short-term without continued treatments (Alaback and Tappeiner 1984, Alaback and Herman 1988, Hanley et al. 1989, Hanley et al. 2013, Crotteau et al. 2020). The repercussions of timber harvest persist for decades, such that forest complexity and forage availability are reduced until forests return to an old-growth stage, at 200 years or more post-harvest (Alaback 1984). Selection for harvested stands can reduce fitness of deer by increasing risk of death due to malnutrition, hunter harvest, and predation (Farmer et al. 2006). In contrast, the dense multi-layered canopy of old-growth forest allows light to penetrate and produce forage while also intercepting snow, resulting in lower snow depths that make it easier for small-bodied deer to move around and access forage (Wallmo and Schoen 1980, Kirchhoff and Schoen 1987, Hanley and Rose 1987). Snow depths of 25 cm or more can increase energy expenditures, limit deer movements, and bury shrubby forage (Parker et al. 1984, Parker et al. 1999, White et al. 2009). Winter severity reduces forage availability and consequently deer survival (Klein and Olsen 1960).

Past studies of deer in Southeast Alaska attempted to discern the direction and strength of deer selection for old-growth versus clearcut forests in winter (Schoen and Kirchhoff 1985, Yeo and Peak 1992, Doerr et al. 2005, Person et al. 2009). However, results differed among studies and researchers continue to debate the degree to which deer rely on old-growth forest for survival, particularly during winters with deep and persistent snow. For example, Schoen and Kirchhoff (1990) studied deer on northern Admiralty Island and concluded that low elevation (<300 m), intact (unharvested) stands classified as productive old-growth (hereafter POG) provided the most important habitat for deer during deep snow conditions. However, their results were limited in scope, as harvested stands made up only a small proportion of forested habitat in their study area. Further, the importance of POG versus stands regenerating from harvest could vary along a latitudinal gradient because snowfall is generally greater in the northern part of the region.

Most previous studies of habitat use by deer in this region (Schoen and Kirchhoff 1990, Yeo and Peak 1992, Doerr et al. 2005, Person et al. 2009) relied primarily on aerial very high frequency (VHF) radiotelemetry, which has limited sample size, location accuracy, and temporal scope of inference. In most cases, animals wearing the transmitting collars can be located only during daylight hours in favorable weather. Only Gilbert et al. (2017) deployed GPS collars on Sitka black-tailed deer. That study collected fine-scale (2-hr fixes) movement and habitat selection data and reported that snow was the dominant driver of habitat selection within deer home ranges, with the strength of selection for POG increasing with greater snow depths (i.e., an interaction). While the same pattern did not exist for young (<30 yr) second-growth forests, Gilbert et al. (2017) found a weaker but similar interaction with older (≥30 yr) second-growth forest and snow, and that individual deer exhibited stronger selection for habitat types as those types became more abundant in their home range (i.e., a functional response; Mcloughlin et al. 2010).

To help fill knowledge gaps, from 2009 through 2013 ADF&G conducted a research project to improve understanding of deer habitat selection. Our primary research objective was to model habitat selection by deer on winter range using resource selection functions (RSFs) paired with high-resolution (~8–15 m accuracy) GPS-collar data and provide a framework by which land managers can predict important winter habitat for Sitka black-tailed deer. We specifically wanted to test deer selection strength and direction for intact POG and previously harvested second-growth forest habitats on Chichagof Island in northern Southeast Alaska. We predicted that deer would select for POG during winter (Schoen and Kirchhoff 1990) and select against previously harvested second-growth stands. Additionally, we predicted that elevation (as a proxy for snow depth) would be a dominant driver of habitat selection (Doerr et al. 2005, Person et al. 2009), with deer selecting against higher elevation terrain. Because migratory deer (those that use alpine terrain above 600m elevation in summer) and resident deer (those that remain below 600m elevation) have been observed to use habitat types differently in British Columbia (McNay and Doyle 1987, McNay and Bunnell 1994) and northern California (Bose et al. 2018), we modeled each group separately.

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Study Area

Chichagof Island is in the Alexander Archipelago of Southeast Alaska and is the fifth largest island in the United States at approximately 5,300 km^2. Our study area was located primarily on lands managed by the U.S. Forest Service, Tongass National Forest on northeast Chichagof Island, approximately 60 km southwest of Juneau, Alaska. We delineated a 259 km^2 study area by constructing a 95%-kernel density polygon (centroid N 57.861° W 135.118°) from all deer GPS locations collected during 2009–2013 and clipped it to the marine shoreline (Fig. 1). The study area is connected to the community of Hoonah (population 800) to the north by a system of gravel logging roads. Annual deer harvest on northeast Chichagof Island averaged 628 deer across regulatory years 1997–2013,[1] about 7% of total deer harvest in Southeast Alaska (ADF&G 2021).

The study area consists of stream valleys and rugged mountainous terrain that extends from sea level to 1,200 m. Subalpine and alpine vegetation are found at elevations above 500 m, while conifer forests are interspersed with muskeg bogs, unproductive scrub forest, wet meadows, and estuaries at lower elevations (Alaback 1988). The old-growth forest overstory is dominated by western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*) and Alaska yellow cedar (*Callitropsis nootkatensis*) (Alaback and Juday 1989, Martin 1989). The understory can vary depending on site-specific conditions and may be dominated by blueberry (*Vaccinium spp.*), rusty menziesia (*Menziesia ferruginea*), or devil's club (*Oplopanax horridus*). Examples of common forbs important to deer in winter include bunchberry (*Cornus canadensis*), five-leaved bramble (*Rubus pedatus*), and fernleaf goldthread (*Coptis aspleniifolia*) (Schoen and Kirchhoff 1983).

Annual total precipitation measured near sea level at the nearby Hoonah airport averaged 157 cm 1998–2018 (NWS 2019). Snow can accumulate in winter and may persist for 7 to 9 months in areas above 600 m, where snow depths often exceed 2 m, making alpine and subalpine habitats unavailable to deer (Parker et al. 1984). In contrast, low elevations receive less snow and can become snow-free for days or weeks at a time during mild winters (NWS 2019). Daily snow depth and total annual snowfall varied during the winters of the study as measured at the nearby Hoonah airport (Fig. 2A–B).

Northeast Chichagof Island has been managed extensively by the USFS and two Alaska Native corporations for commercial timber harvest. After more than 40 years of logging, the remaining forest is a mosaic of commercially valuable POG and harvested stands of varying ages, some of which have been thinned. As of 2012, 27 km^2 (11%) of the study area had been harvested. Landcover classes comprised the following percentages of the study area: non-forest (25%), unproductive forest (15%), smaller POG forest (29%), larger POG forest (21%), young, harvested stands ≤15 years of age (7%), and older harvested stands >15 years of age (4%). The area is accessible to hunters via the shoreline and logging roads and receives moderately high hunting pressure, with a 6-month open season for deer, 1 August–31 January. Brown bear (*Ursus arctos*) are the sole predator of deer on Chichagof Island but are not active during winter and are likely similar to black bears (*Ursus americanus*), which prey on deer fawns primarily during the first 30 days of a fawn's life (Gilbert 2015).

[1] A regulatory year begins 1 July and ends 30 June (e.g., regulatory year 1997 = 1 July 1997–30 June 1998.

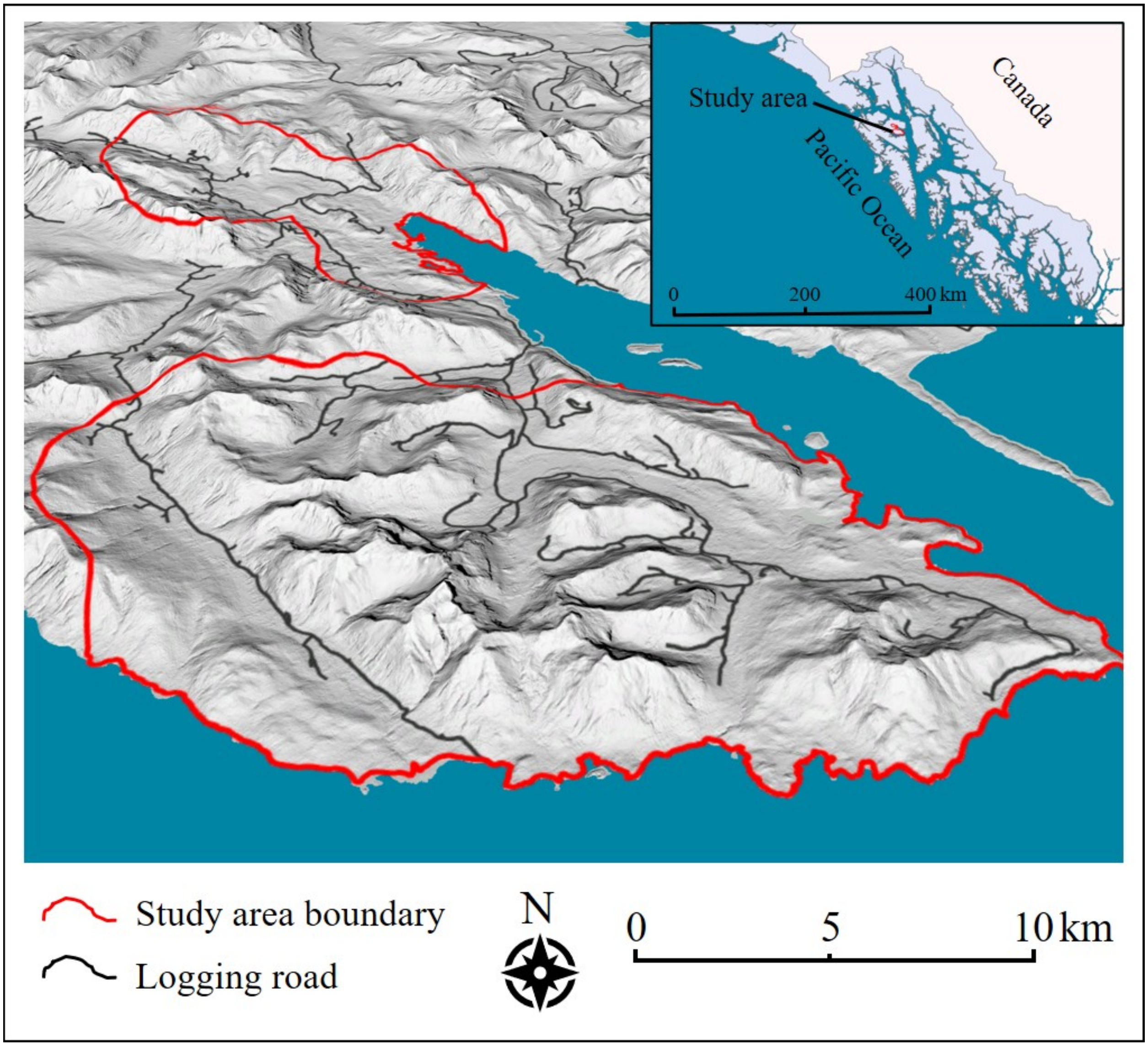

Figure 1. Study area for Sitka black-tailed deer collared on Chichagof Island, Southeast Alaska, during 2010–2013.

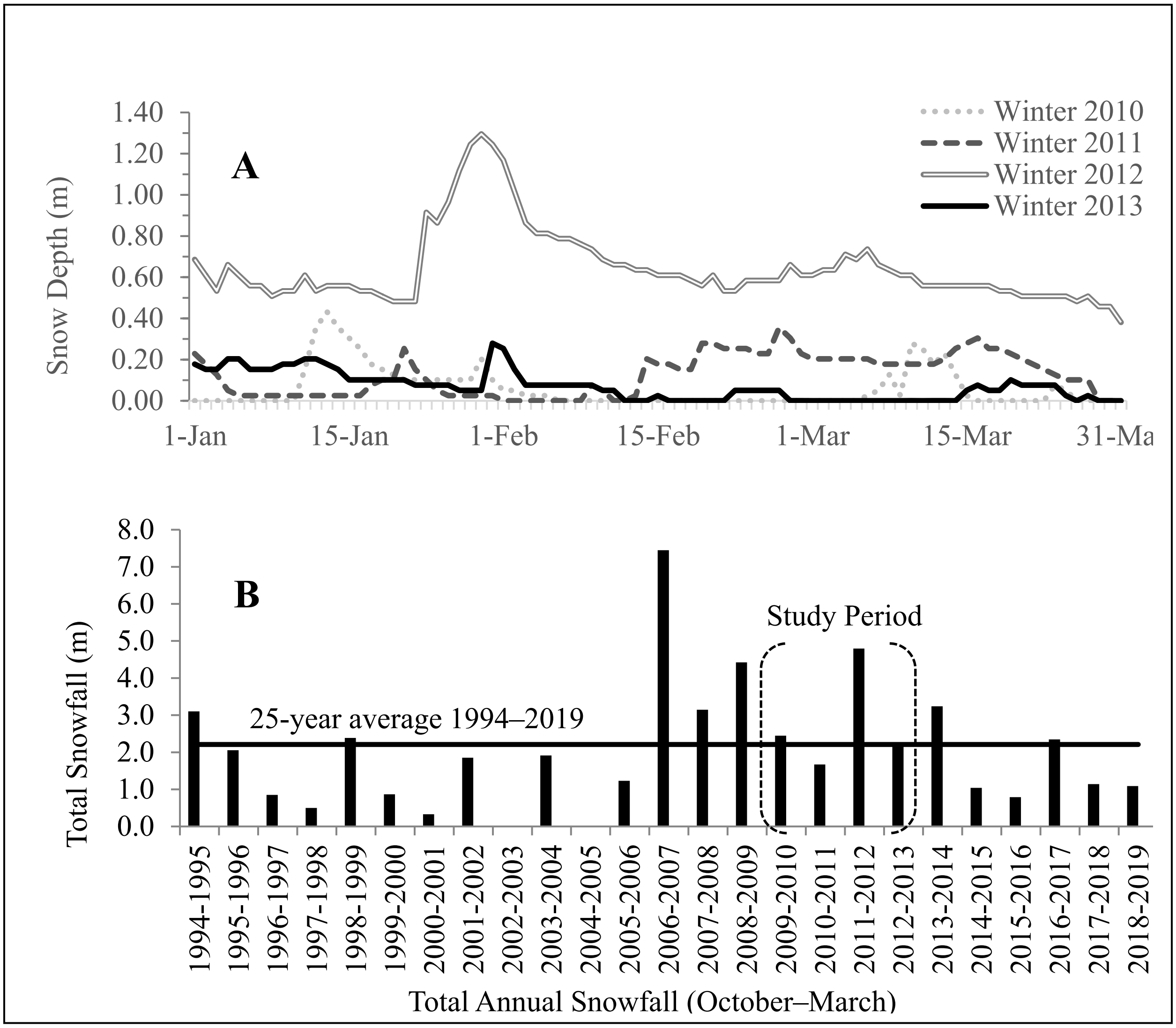

Figure 2. Variability of snow depth and annual snowfall on northeast Chichagof Island at the Hoonah airport weather station (6 m elevation) showing A) daily snow depth (m) by winter during the study period and B) total annual snowfall (m) by winter, with study period in brackets. Figure adapted from Gilbert et al. (2017).

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Methods

Capture

During June–October of 2009–2013, ADF&G staff used standard ground-based darting techniques and a Pneu-Dart 389 dart projector (Pneu-Dart, Barbours, PA) to capture deer adjacent to logging roads. A professional helicopter capture team consisting of ADF&G staff and contracted pilot also captured deer by netgunning from a helicopter in alpine habitats during August of 2010. Ground-darted deer were immobilized with either a mixture of Telazol® (191 mg) and xylazine (77 mg), the xylazine antagonized with tolazoline (72 mg), or a mixture of ketamine hydrochloride (140 mg) and medetomidine HCL (6 mg), the medetomidine antagonized by atipamezole (22mg). Standard veterinary protocols were used for each capture method for handling, collecting routine samples and data, and attaching a Telonics TGW 3500 GPS radio collar (Telonics, Inc., Mesa, AZ) to deer. All captures and handling procedures were approved by the ADF&G Division of Wildlife Conservation Institutional Animal Care and Use Committee (ACUC protocol 08-09).

Habitat Selection Analysis

We defined the winter analysis period as 1 January–31 March in each study year. Although winter could be defined as a longer period, we wanted to analyze habitat use within a core winter period to ensure exclusion of any early or late exploratory movements between deer seasonal ranges. Because fix rates varied across deer, we rarefied GPS location data to a common 6-hr fix rate across all individuals and years to avoid sample size bias. We only included deer in the analysis for which we had GPS locations across >75% of the winter period. Based on prior research (Schoen and Kirchhoff 1985, 1990), we analyzed the deer displaying resident and migratory movement tactics separately. We defined resident deer as those remaining at lower elevations (<600 m) throughout the year, while migratory deer frequented high elevation (≥600 m) areas in summer through late fall.

We constructed Resource Selection Functions (RSFs) using a use-versus-availability design (Type II design, Manly et al. 2002) in a logistic regression framework. We generated available points randomly within our study area (second order selection; Johnson 1980) using the function sampleRandom in the raster package (Hijmans 2020) in Program R (R version 4.0.0, www.r-project.org). We created 1,000 available points per square kilometer (~286,000 points), then subsampled to 10,000 points due to computing constraints (Northrup et al. 2013). These available points were then compared to locations used by resident and migratory deer.

We built models with categorical covariates of land cover classes and of other continuous landscape metrics (Table 1). Land cover classes were based on USFS land cover databases describing forest cover (‘CoverType’ database) and timber harvest and thinning activities (‘FACTS’ database) on the TNF. Although other habitat data were available for our study area, we chose the USFS CoverType data because this forest classification system is well-documented (Caouette and DeGayner 2008), is used by the USFS for forest management, and covers Southeast Alaska, allowing extrapolation of our results to other areas. To ensure an adequate number of deer locations in each landcover class, TNF land cover classes were combined into broader categories.

Harvested stands become depauperate of understory at approximately 30 years (Alaback 1982, 1984), but because only 8% of harvested stands in our study area were over 30 years of age, such a grouping would not likely have been informative for our study area. Production of herbaceous forage is highest in harvested stands prior to the onset of canopy closure at approximately 15 years of age (Alaback 1982, Farmer et al. 2006), so we included both young (≤ 15 yr) and old (>15 yr) harvested stand age-class groupings in RSF models. Thinned stands can have twice the understory biomass of unthinned stands through a decade post-treatment, after which canopy cover notable increases (Crotteau et al. 2020). Since recent timber harvest areas and recently thinned forest are similar in having a more open canopy and higher understory growth, we grouped harvested stands of ages <15 years with thinned areas of ages <15 years as one habitat class and harvested stands ≥15 years with thinned areas of ages ≥15 years as another.

We used the USFS definition of POG forest as those lands with a mapped volume of timber >8,000 board feet/acre (USFS 2016). We modeled deer selection using the USFS size-density classes 4 and the combined classes 5, 6, and 7. These groupings reflect estimated timber volume of 8,000–20,000 and >20,000 board feet/acre respectively (Caouette and DeGayner 2008). Models were run using the R package glmmTMB (Brooks et al. 2017).

As assessing deer selection of habitat classes was of critical importance to the study, we included land cover classes in all candidate models. Candidate models were included in which the two harvested stand ages were both split apart and combined, and in which size-density classes SD4 and SD567 of POG timber were split apart and combined. This allowed us to test whether these distinctions were useful in predicting deer habitat selection. Selection coefficients of these land cover classes were estimated relative to the reference category, non-forest (Hosmer and Lemeshow 2000).

We also included 4 continuous covariates in candidate models: elevation (m), slope (°), solar radiation (Watt*Hours/m^2), and density of edges (km/km^2). We calculated solar radiation in ArcMap 10.5 using the “Solar Radiation” tool. Solar radiation was calculated as a mean for each pixel during the period between 9 a.m. and 3 p.m. over a single day, 1 January 2012. We defined edges as between vegetation types mapped in the USFS CoverType layer having a mostly closed canopy (mature forest, older timber harvest) and open types with little to no canopy cover (e.g., non-forest, young clearcuts). The optimal scale (200-m radius) of the edge density calculation was chosen by including density calculated at 100, 200, 500, and 1,000 m radii in univariate models and choosing the model with the lowest AICc score (Burnham and Anderson 2002). All continuous covariates were scaled as $(x - \text{mean}(x))/2\text{SD}(x)$ to obtain model coefficients comparable across continuous and categorical landcover covariates (Gelman 2008).

We modeled deer habitat selection using generalized linear mixed-effects models (GLMMs) with random intercepts and slopes for individual deer-years (Gillies et al. 2006). These models allow individual deer to differ in their selection patterns yet still output fixed effects that summarize population-level relative probability of use.

Table 1. Covariates (and their sources) used in habitat selection analysis for Sitka black-tailed deer on Chichagof Island 2010–2013.

Covariate	Description	Source
Categorical covariates		
Non-forest	Non-forested classes (reference category). Size-density codes FM, NF, W, X99	USFS TNF CoverType database.
Unproductive forest	Low-volume old growth forest classed as noncommercial. Size-density code UF. (< 8000 board feet/acre).	USFS TNF CoverType database.
POG, size-density class 4	Low to medium volume productive old-growth forest, size-density class 4. Codes S1, S2, S3, SD4H, SD4N, SD4S. (8,000-20,000 board feet/acre)	USFS TNF CoverType database.
POG, size-density classes 5, 6, and 7	Medium to high volume productive old-growth forest, size-density classes 5, 6, &7. CodesSD5H, SD5N, SD5S, SD67, F99. (>20,000 board feet/acre	USFS TNF CoverType database.
Young harvested stand	Harvested or thinned forest (< 15 years since harvest or thin)	USFS TNF FACTS database.
Old harvested stand	Harvested or thinned forest (≥ 15 years since harvest or thin)	USFS TNF FACTS database.
Continuous covariates		
Elevation (m)	Measure of height above sea level	SRTM-DEM
Slope (°)	Measure of terrain steepness	Derived from SRTM-DEM, calculated in R (raster package 'terrain' function).
Solar radiation (Watt Hours/m^2)	Modeled solar radiation on 1 January	Derived from SRTM-DEM, calculated in ArcGIS 10.5.1
Edge density (km/km^2)	Density of edges between open canopy vs. closed canopy habitat classes	Derived from USFS CoverType and FACTS databases, calculated in ArcGIS 10.5.1

Although the inclusion of random intercepts alone is more prevalent in the RSF literature, we also included random slopes, which more properly considers pseudoreplication of habitat covariate values measured for each animal (Muff et al. 2019). In a mixed-effects RSF model, the logit model is estimated as a function of the covariates per the following equation (Gillies et al. 2006):

$$g(x) = ln\left[\frac{\pi(x)}{1-\pi(x)}\right] = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \cdots \beta_n x_{nij} + \gamma_{nj} x_{nj} + \gamma_{0j}, \qquad (1)$$

where $\pi(x)$ represents the probability of use, x_n are landscape factors with fixed regression coefficients β_n, γ_{nj} is the random coefficient for covariate x_n for animal j, and γ_{0j} is the difference between β_0 and the intercept for individual j. We drop the intercept to obtain relative probability of use (Manly et al. 2002).

We performed model selection using a modified all-subsets approach in which models consisting of all possible combinations of the 4 continuous covariates were included along with all 5 land cover classes. We performed model selection by model performance on *k*-fold ($k = 5$) cross-validation. We randomly chose 80% of animals ('training set') to build a model using the covariates of the model being validated, then tested the model's predictions on the remaining 20% animals ('validation set') and repeated this process 5 times until all animals had been included in the validation set (Roberts et al. 2017). The draw of individuals assigned to each training and validation set is random, and so the results vary from one *k*-fold trial to the next. To account for this, we performed 10 trials of *k*-fold cross-validation for each candidate model and calculated the mean Spearman's rho (Johnson et al. 2006) across these trials. We considered the top model that model with the highest mean Spearman's rho score. From the top model coefficients, we calculated the relative selection strength (RSS; Avgar et al. 2017) by deer for the landcover classes as $exp(\beta)$ when all continuous covariates are set to their mean value in the study area. Confidence intervals for all model coefficients and RSS values were calculated at the 95% level

We calculated output raster maps depicting relative probability of use (RPU) by resident and migratory deer (Boyce et al. 2002) from top models via:

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n) \qquad (2)$$

where the $w(x)$ is the relative probability of animal use of a resource unit, the β_n are RSF model coefficients and the x_n the RSF model landscape covariates. To provide a summary raster map of both movement tactics, we also took a mean of the 2 movement tactic maps weighted by the number of deer of each movement tactic. We then binned these mean predictions into 20% quantiles (e.g., 0–20%, 21–40%, 41–60%, 61–80%, 81–100%) indicative of increasing relative probability of use (Johnson et al. 2006) and defined the top 20th percentile as high-quality habitat (Morris et al. 2016). We mapped high-quality habitat for each movement tactic of deer and also created a composite map that overlays these 2 maps to summarize high-quality winter habitat across both movement tactics.

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Results

We deployed 28 GPS radio collars on deer captured during 2009–2013. Of these, 22 collected data across at least 75% of the seasonal date range and met our requirements to be included in the analysis. Of deer included, 8 were defined as resident deer (7 females, 1 male) and 14 were defined as migratory (10 females, 4 males). All migratory deer were captured using a net gun in the alpine except one individual that was captured by ground-darting off a mid-elevation road in early summer. All resident deer were captured via ground-darting at relatively low elevations. Five deer (2 resident and 3 migratory) had more than one year of complete winter seasonal data. Models were built using 10 resident deer-years and 17 migratory deer-years with a mean (±SD) of 316.6 (±31.8) and 302.4 (±35.9) number of locations per deer-year respectively. Deer locations were attributed with covariate values that varied widely across individual deer (Appendix A). The highest frequency of winter resident locations occurred below 100 m elevation (range 3–431m), while most winter migratory deer locations occurred above 100 m (range 8–667 m; Fig. 3A). Availability of POG forest (Fig. 3B), harvested stands, and non-forest reference classes (Fig. 3C) also varied by elevation.

The top models for resident and migratory deer (Table 2), as determined by cross-validation performance, had Spearman's rho values statistically higher than competing models (*P*-value <0.001; Appendix B, Tables B1 and B2). In the top model for resident deer, all POG forest classes (the SD4–7 classes combined) were combined rather than split apart, indicating no detected difference in deer selection for the two POG groups. The top model for migratory deer also indicated selection for POG forest, though this model separated the SD4 and SD567 classes. Selection for SD4 by migratory deer was strongly positive, but selection for SD567 was weaker and ambiguous, with a confidence interval surrounding zero. The resident deer RSS (i.e., $exp(\beta)$) for all POG forest was 5.64 times (95% CI: [2.40, 13.25]) that of the non-forest reference class (Table 3). Migratory deer RSS for SD4 POG forest was 14.34 times (95% CI: [1.78, 115.54]) that of the non-forest reference class, and the strongest selection for any habitat class. Migratory deer strongly selected against unproductive forest, while resident deer tended to select for it, though with confidence interval slightly overlapping 0. Resident deer RSS for unproductive forest was 3.49 times (95% CI: [0.98, 12.36]) that of the non-forest reference class (Table 3).

Top models for both movement tactics lumped young and old harvested stands together, indicating that deer selection for managed forests were similar regardless of age (Table 2). Resident and migratory deer did not select harvested stands over the non-forest habitat class; the coefficients of harvested stands for both deer movement tactics were negative but small with CIs overlapping zero, indicating they were used in proportion to their availability. Harvested stands and unproductive forest were relatively more abundant at elevations below 200 m, where resident deer occur (Fig. 3A–C). Parameter estimates did not change greatly across all the models considered, with multiple models having Spearman's rho values marginally less than the top model, particularly for resident deer (Appendix B, Tables B1and B2).

Several continuous variables were also included in the top models for both resident and migratory deer. Elevation was a strong predictor for both the resident and migratory deer top models. The coefficient for elevation was negative in the models for both movement tactics and was particularly large for resident deer (Table 2), which spent winters within a lower and narrower elevation band than migratory deer (Fig. 3A). Migratory deer rarely used the lowest elevations (Fig. 3A). Edge density was also included in the top models for both movement tactics. Edge density for migratory deer was strongly negative ($\beta = -2.00$, CI: [−3.18, −0.83]). In contrast, the coefficient for edge density for resident deer was positive, but small and with a confidence interval that overlapped zero (Table 2), indicating edge environments were used in proportion to availability.

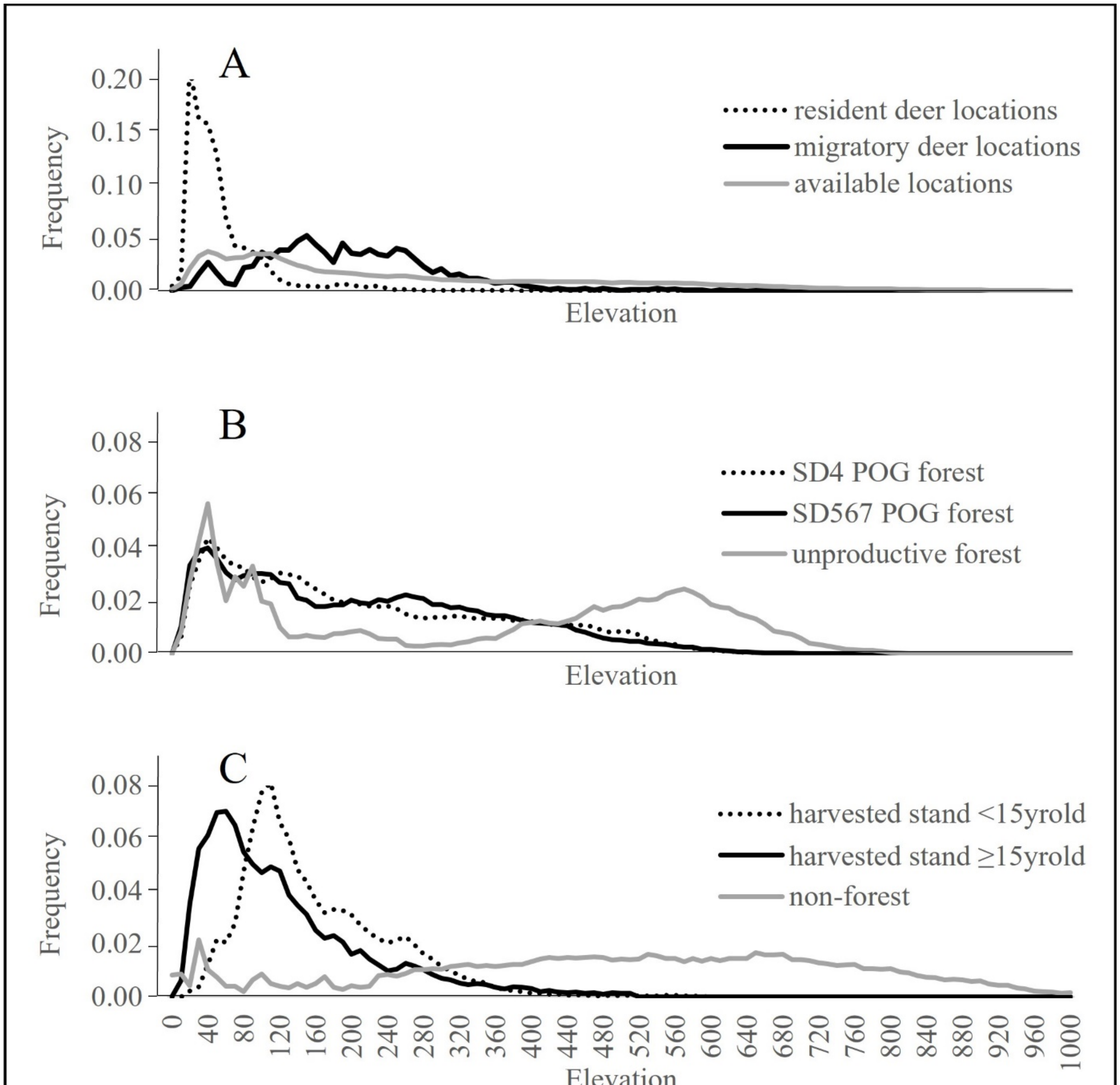

Figure 3. Frequency distribution of deer locations by elevation in the study area, northeast Chichagof Island, Southeast Alaska, of A) available points and deer locations collected during the study period winters, 2010–2013, B) productive old-growth (POG; > 8,000 board feet) forest by USFS size-density (SD) class and C) harvested stands and non-forest.

Table 2. Top GLMM model coefficients (β) and lower (LCL) and upper (UCL) 95% confidence levels from resource selection function (RSF) models of resident and migratory deer, Chichagof Island, Alaska, during winters 2010–2013.

	Resident			Migratory		
Covariate[1]	Β	LCL	UCL	β	LCL	UCL
Elevation (m)	−17.00	−24.23	−9.78	−1.96	−3.96	0.05
Slope (°)	–[2]	–	–	0.09	−0.89	1.08
Solar radiation (Watt Hours/m^2)	−0.83	−2.06	0.40	–	–	–
Edge density (km/km^2)	0.38	−0.17	0.93	−2.00	−3.18	−0.83
Unproductive forest	1.25	−0.02	2.51	−8.08	−14.83	−1.31
SD4 forest	–	–	–	2.66	0.58	4.75
SD567 forest	–	–	–	0.77	−1.26	2.81
All POG forest[2]	1.73	0.88	2.58	–	–	–
Harvested stands[3]	−0.21	−0.72	0.29	−0.13	−0.71	0.44

[1] Reference category was non-forest.
[2] En dash indicates covariate was not included in top model.
[3] Grouping of SD 4–7 POG forest.
[4] Grouping of young and old harvested stand categories.

Table 3. Relative strength of selection (RSS) and lower (LCL) and upper (UCL) 95% confidence levels for landcover classes from top RSF models for resident and migratory deer, Chichagof Island, Alaska, during winters 2010–2013.

	Resident			Migratory		
Covariate[1]	RSS	LCL	UCL	RSS	LCL	UCL
Unproductive forest	3.49	0.98	12.36	0.01	0.00	0.27
SD4 forest	–	–	–	14.34	1.78	115.54
SD567 forest	–[2]	–	–	2.17	0.28	16.61
All POG forest[3]	5.64	2.40	13.25	–	–	–
All harvested stands[4]	0.81	0.49	1.33	0.87	0.49	1.56

[1] Reference category was non-forest.
[2] En dash– indicates covariate was not included in top model.
[2] Grouping of SD 4–7 POG forest.
[3] Grouping of young and old harvested stand categories.

Other continuous covariates were less influential and had CIs overlapping zero. Slope was not included in the top resident deer model and had a small and nonsignificant coefficient in the migratory deer model, with a CI almost centered on zero. Solar radiation was not included in the top migratory deer model and had a small negative coefficient in the top resident model, with a CI that overlapped zero.

The predictions from the top models resulted in mapped RPU values that varied widely across the study area. The top 20th percentile of mapped RPU (Fig. 4) illustrates how resident deer have a greater preference for lower elevation habitat than migratory deer (Fig. 5). When the top 20th percentile of RPU values for all deer are combined (Fig. 6), high quality winter habitat constitutes approximately 33% of the study area.

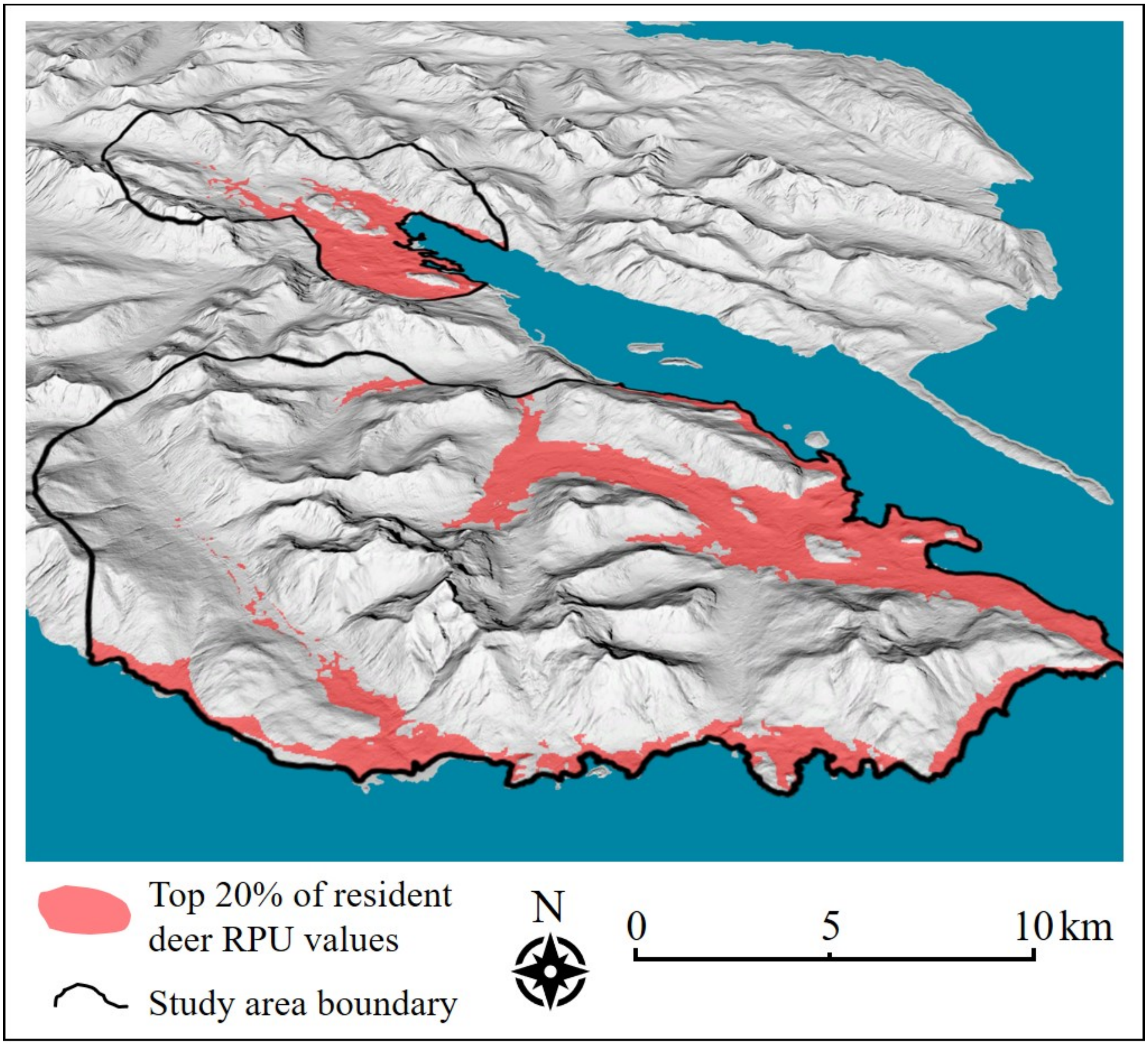

Figure 4. Top 20th percentile of relative probability of use (RPU) during winter of resident Sitka black-tailed deer. Map depicts the areas most important to resident deer, as determined by habitat selection across the study area, Chichagof Island, Alaska 2010–2013.

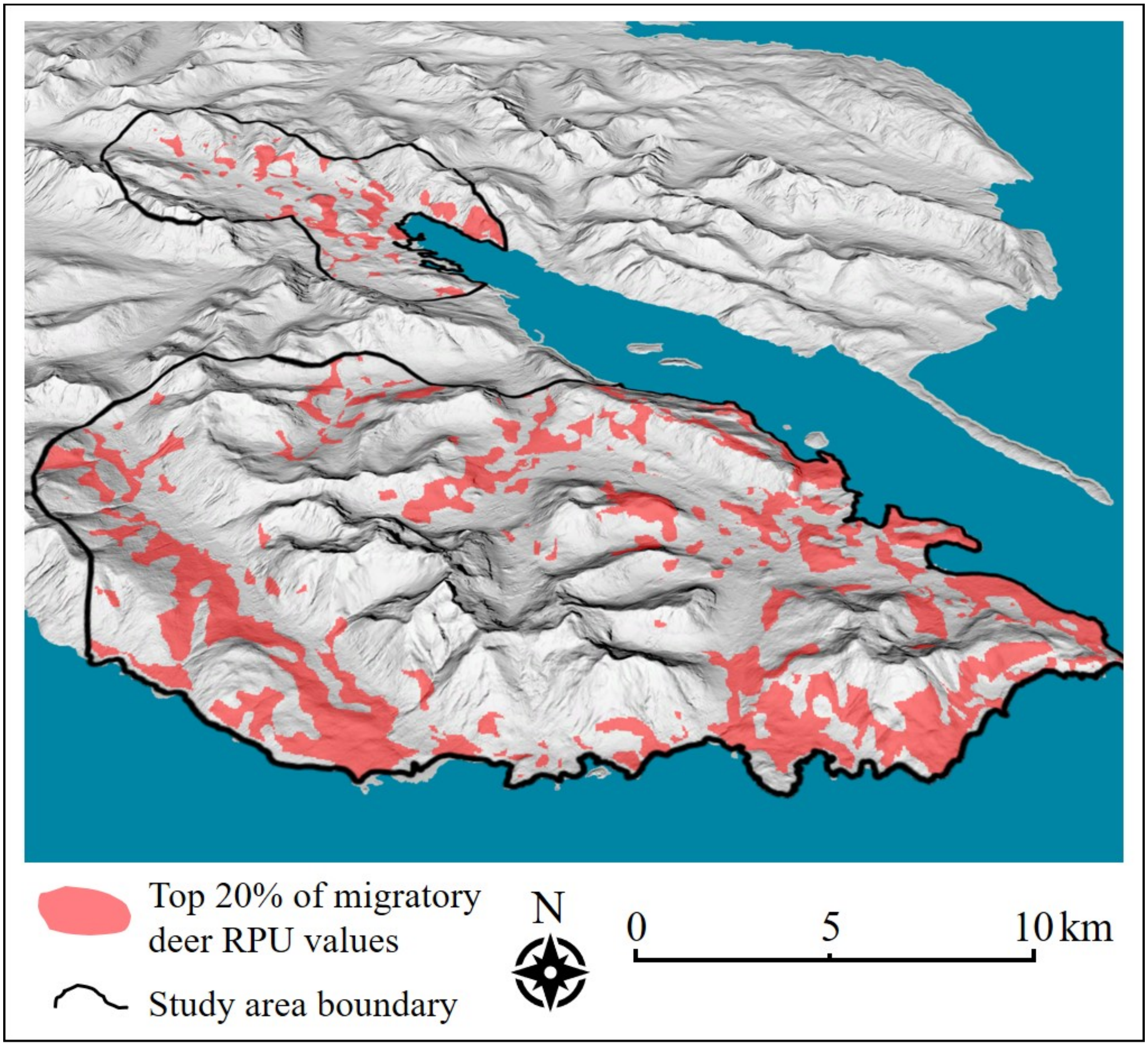

Figure 5. Top 20th percentile of relative probability of use (RPU) during winter of migratory Sitka black-tailed deer. Map depicts the areas most important to migratory deer, as determined by habitat selection across the study area, Chichagof Island, Alaska 2010–2013.

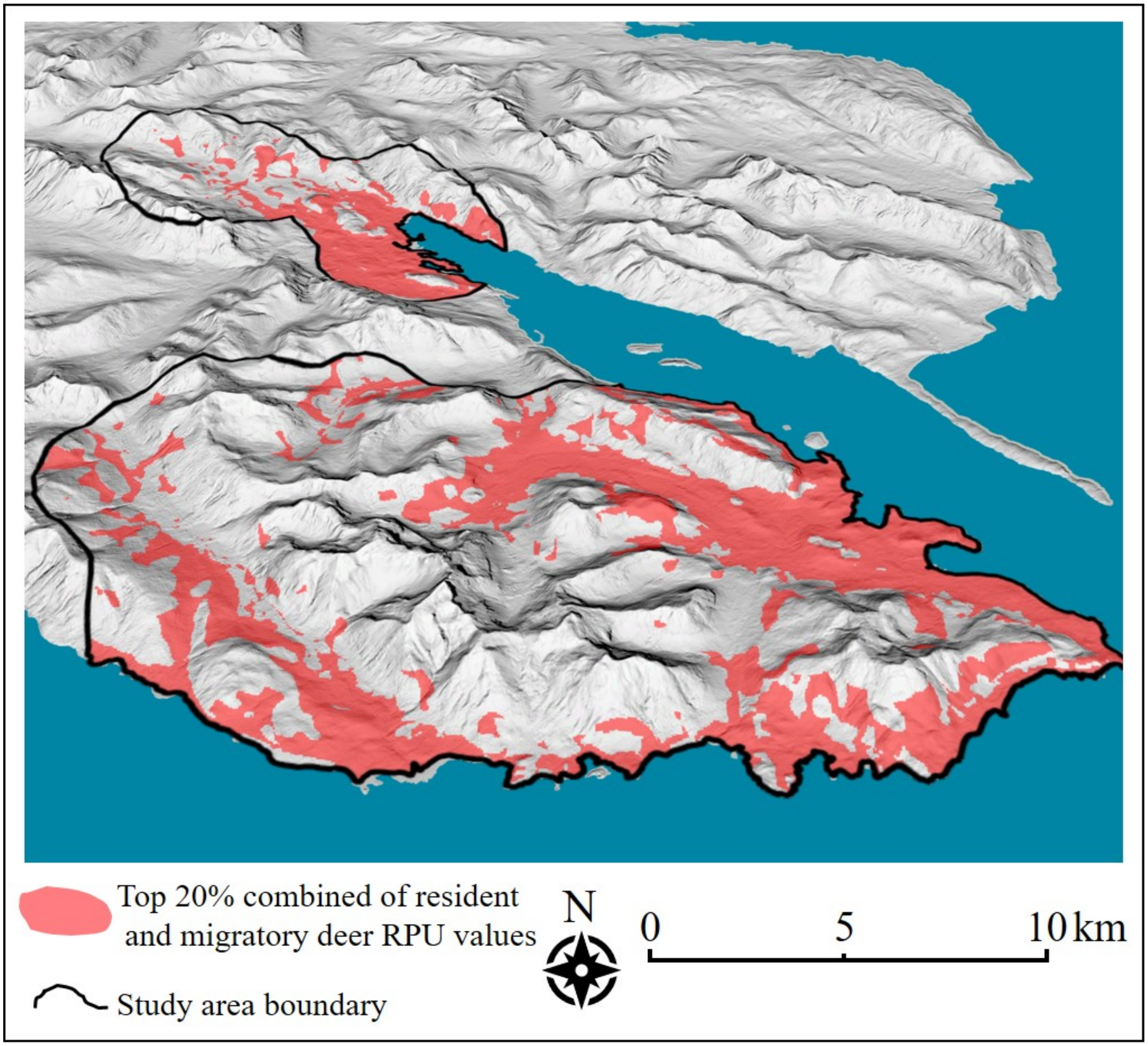

Figure 6. Top 20th percentile of relative probability of use (RPU) during winter of both resident and migratory Sitka black-tailed deer Map depicts the areas most important to deer, as determined by habitat selection across the study area, Chichagof Island, Alaska 2010–2013.

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Discussion

We developed winter habitat selection models using GPS collar data that compared selection of POG vs. harvested stands and other predictors of deer habitat selection for resident and migratory Sitka black-tailed deer during winters with average to above-average snowfall. Our results showed that both resident and migratory deer strongly selected for POG forest, with migratory deer RSS for the SD4 class of POG being the strongest for any habitat class. Although not significant, there was a tendency in both our top models and competing models for both resident and migratory deer to select against harvested stands. Results indicated that while migratory deer strongly avoided unproductive forest, resident deer strongly selected for it. However, resident deer RSS for POG was substantially stronger than RSS for unproductive forest, indicating that when both are locally abundant in winter, POG forests are likely of higher value.

Elevation dominated predictions for resident deer with a large negative coefficient, reflecting strong selection for lower elevations during winter. For migratory deer, elevation was less important compared to habitat categories, reflecting their tendency to select for slightly higher elevations in winter compared to residents. Migratory deer selection was most strongly driven by their avoidance of unproductive forest followed by selection for SD4 POG forest. We also found that migratory deer avoided forest edges, while resident deer used them in proportion to their availability. Both slope and solar radiation were inconsequential for predicting habitat selection by deer regardless of migration tactic.

Our results generally agreed with previous studies that found deer selected for old-growth forest in winter, although we note that the Schoen and Kirchhoff (1990) study on nearby Admiralty Island found greater use by mostly migratory deer of high-volume (SD567) versus low-volume (SD4) POG in winter, regardless of snow conditions. We found that migratory deer tended to select for low-volume POG even though they had similar amounts of low- and high-volume POG available to them. This could be explained by the greater frequency (larger sample size) and accuracy of deer locations collected in this study using GPS collars or by differences in habitat availability between the two study areas. In addition, because VHF-based deer location data in prior studies was likely biased due to a lack of data collection during night and crepuscular hours when deer actively forage, they may have failed to capture deer selection for this habitat class (Northrup et al. 2015). Other researchers have suggested that deer exhibit stronger selection for certain habitats as those habitats become more available on the landscape (Person et al. 2009; Gilbert et al. 2017). It is also possible that remaining high-volume forest in our study area may have primarily occurred on northernly aspects with greater and/or more persistent snow (Doerr et al. 2005, Person et al. 2009). For instance, Person et al. (2009) found that deer selection for old-growth forest depended on aspect, with increasing selection for high-volume POG on south-facing aspects. Finally, it could be that because shrubs in low-volume POG forest are taller and more abundant than in high-volume forest (Kirchhoff and Schoen 1987), the benefits of greater forage availability outweigh increased energetic costs of movement (Hovey and Harestad 1992).

For resident deer, our findings resembled selection patterns from 2 studies conducted in southern Southeast Alaska, where deer selected for unproductive forest during winters with snow (Person 2009), and when that habitat was more locally abundant (Gilbert et al. 2017). Selection for this low-volume old growth forest habitat by resident deer in our study likely reflects the greater amount of commercially unproductive forest and POG fragmentation at lower elevations in our study area, where the greater abundance of forage in this habitat class may remain accessible during periods of low snow. In contrast, the negative selection for unproductive forest by migratory deer was the strongest of any habitat variable. Forage in higher elevation unproductive forest where migratory deer occur is likely buried under deeper snow, making it less attractive compared to the unproductive forest available to resident deer inhabiting lower elevations. Prior research has indicated both selection for (Person 2009, Gilbert et al. 2017) and against (Schoen and Kirchhoff 1990, Yeo and Peek 1992, Doerr et al. 2005) unproductive forest. Our findings corroborate prior research indicating that while POG forest provides important winter range, other habitats with greater forage abundance, such as unproductive forest, are also important when snow is less deep (Hanley 1984).

Among continuous covariates, selection for elevation was strongly negative for both resident and migratory deer, but particularly for resident deer, where the coefficient was about 10 times the magnitude of any other coefficient (Table 3). This reflects that resident deer tend to remain at low elevation and possibly reflects the extent to which snow accumulation can constrain deer in winter. These results corroborate patterns reported by previous research (Schoen and Kirchhoff 1985, Schoen and Kirchhoff 1990, Doerr et al. 2005, Person et al. 2009, Gilbert et al. 2017). Schoen and Kirchhoff (1985, 1990) reported similar findings; both movement tactics seek out relatively low elevation, but resident deer have a stronger selection for lower elevations than migratory deer. Because snow depth generally increases with elevation (Grunewald et al. 2014), deer are likely avoiding high elevation terrain due to deeper snow there.

While selection for edge density was weakly positive and ambiguous for resident deer, it was strong and unambiguously negative for migratory deer. Black-tailed deer have been shown to select for edges (Chang et al. 1995, Doerr et al 2005), but also to avoid them while resting (Bose et al. 2018). It is possible that migratory deer avoided edges to seek thermal protection in sheltered areas (Bunnell 1990, Mysterud and Ostbye 1999, Doerr et al. 2005). We defined edges as areas that transition from closed to open canopy habitat types, which is likely also a transition from shallower to deeper snow depths, especially at the higher elevations that migratory deer frequent. As such, selection against edge also may be analogous to selection against deeper snow conditions. Timber harvest increases edge and decreases the amount of thermal cover, which may have greater consequences as elevation increases and climatic conditions become more severe.

We found only weak negative selection for harvested stands; deer tended to weakly avoid harvested stands relative to the availability of this habitat on winter range, and we found no evidence that deer responded differently to younger and older harvested stands. All other telemetry studies in Southeast Alaska that included deer within logged watersheds reported that deer selected harvested stands that were less than 20 years old during snow-free months (Yeo and Peek 1992, Farmer 2002, Doerr et al. 2005) while most concluded that deer avoided older harvested stands (also known as stem-exclusion seral forest; Person et al. 2009). While harvested stands produce abundant deer forage in the years immediately following timber harvest (Gilbert et al. 2017), this forage becomes largely unavailable when buried by snow (White et al. 2009). At 20–35 years post-harvest (depending on site conditions), the dense, even-aged canopy of regenerating trees can become so thick that the understory becomes depauperate of forage (Alaback 1982, Hanley 1984). However, Doerr et al. (2005) reported that deer use of older second-growth forest was similar to that of younger harvested stands and attributed that use to pre-commercial thinning, which is one of the few tools available to restore forage productivity to harvested stands. We also found little difference in selection for young and older harvested stands. The top selected models grouped young (<15 years old) and older (≥15 years old) harvested stands together as one habitat class for resident and migratory deer.

This study supports prior studies indicating that deer generally select for POG forests (Schoen and Kirchhoff 1990, Doerr et al. 2005, Person et al 2009), but strength of selection for individual habitat classes may vary depending on conditions such as snow depth or habitat composition (Gilbert et al. 2017). Relative to our whole study area, resident deer home ranges were more likely to be at low elevation (<100 m), flat, and characterized by patchily forested habitat with a variety of habitat classes. Migratory deer selected home ranges to include larger patches of POG forest at low to mid elevations, where unproductive forest habitat is rare. For many of our predictors, especially habitat types, there was substantial variability of location data among individuals (Appendix A). For example, most migratory deer were not located in older harvested stands, but some migratory deer were located many times in this type of stand. This bi-modal pattern likely increased uncertainty in parameter estimates for this habitat class, and probably was the result of site-specific snow accumulation and habitat composition. Gilbert et al. (2017) also noted high variability in selection among individuals, and concluded that habitat selection in winter is flexible, where deer select more available habitats as determined by both locally available habitat composition and the influence of snow. Because the habitat composition and snow depths experienced by migratory deer in our study area are generally different than those experienced by resident deer, and habitat selection differed between them, our study supports this conclusion.

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Management Implications

In TLMP, the USFS has designated Sitka black-tailed deer as a forest management indicator species due to their strong association with POG forest habitat. Balancing the habitat needs of deer with logging activity in economically valuable POG forest has been a management goal of the USFS for decades. TLMP Standards and Guidelines direct forest managers to consider deer habitat needs during environmental analysis and project planning processes, and to use the interagency habitat capability model to assess the effects of proposed activities on deer habitat (USFS 2016). Land managers can use the information from this study when reviewing and updating habitat suitability models to ensure habitat scores reflect the best available data.

This study is the first to use high-resolution GPS location data collected under all weather conditions during day and night to learn about habitat selection by deer in northern Southeast Alaska. These data provide a more comprehensive picture of habitat selection of deer than previous studies based on VHF location data. The models we developed can be used to evaluate the likely long-term effects of past and future timber harvest on deer living under habitat and environmental conditions similar to our study area. The mapping framework provided by this study can be used to delineate deer winter range on the landscape and help inform a management approach that balances the unique habitat requirements of both resident and migratory deer with timber resource values.

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Literature Cited

Alaback, P. B. 1982. Dynamics of understory biomass in Sitka spruce-western hemlock forests of Southeast Alaska. Ecology 63:1932–1948.

Alaback, P. B. 1984. Secondary succession following logging in the Sitka spruce western hemlock forests of southeast Alaska: Implications for wildlife management. USDA Pacific Northwest Forest and Range Experiment Station General Technical Report PNW-GTR-173.

Alaback, P. 1988. Endless battles, verdant survivors. Natural History 97:45–48.

Alaback, P., and G. P. Juday. 1989. Structure and composition of low elevation old-growth forests in research natural areas of southeast Alaska. Natural Areas Journal 9:27–39.

Alaback, P. B., and F. R. Herman. 1988. Long-term response of understory vegetation to stand density in Picea-Tsuga Forests. Canadian Journal of Forest Research 18(12):1522–1530.

Alaback, P. B., NOWdata and J. C. Tappeiner. 1984. Establishment report: Response of understory vegetation to thinning in the Sitka spruce-western hemlock forests of southeastern Alaska. Unpublished report, Forestry Sciences Laboratory. Juneau.

Alaska Department of Fish and Game (ADF&G) 2021. Deer hunter survey summary statistics, WinfoNet database. Division of Wildlife Conservation, Juneau. (Accessed 15 June 2021)

Avgar, T. S. R. Lele, J. L. Keim, and M. S. Boyce. 2017. Relative selection strength: Quantifying effect size in habitat; and step-selection inference. Ecology and Evolution. 7(14):5322–5330.

Bose, S., T. D. Forrester, D. S. Casady, H. U. Wittmer. 2018. Effect of activity states on habitat selection by black-tailed deer. Journal of Wildlife Management 82:1711–1724.

Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157:281–300.

Brinkman, T. J., F. S. Chapin, III, G. Kofinas, and D. K. Person. 2009. Linking hunter knowledge with forest change to understand changing deer harvest opportunities in intensively logged landscapes. Ecology and Society 14(1):36. [online] http://www.ecologyandsociety.org/vol14/iss1/art36/

Brooks, M. E., K. Kristensen, K. J. van Benthem, A. Magnusson, C. W. Berg, A. Nielsen, H. J. Skaug, M. Machler, and B. M. Bolker. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal 9:378–400.

Bunnell, F. 1990. Ecology of black-tailed deer. Pages 31–63 [*In*] J. B. Nyberg and D. W. Janz, editors. Deer and elk habitat in coastal forests of southern British Columbia. Special Report Series. Research branch British Columbia Ministry of Forests, Victoria, Canada.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multi-model inference: A practical information-theoretic approach. Springer-Verlag, New York.

Caouette, J. P., and E. J. DeGayner 2008. Broad-scale classification and mapping of tree size and density attributes in productive old-growth forests in Southeast Alaska's Tongass National Forest. Western Journal of Applied Forestry 23(2):106–112.

Chang, K. T., D. L. Verbyla, and J. J. Yeo. 1995. Spatial analysis of habitat selection by Sitka black-tailed deer in southeast Alaska, USA. Environmental Management 19:579–589.

Crotteau, J. S., A. Z. Rue-Johns, and J.C. Barnard, 2020. Effects on understory biomass and forage 8–10 years after precommercial thinning of Sitka spruce–western hemlock stands in southeast Alaska. Canadian Journal of Forest Research 50(2):215-22.

DeCesare, N. J., M. Hebblewhite, F. Schmiegelow, D. Hervieux, G. J. McDermid, L. Neufeld, M. Bradley, J. Whittington, K. G. Smith, L. E. Mogantini, M. Wheatly, and M. Musiani. 2012. Transcending scale dependence in identifying habitat with resource selection functions. Ecological Applications 22:1068–1083.

DellaSalla, D. A. 2011. Temperate and boreal rainforest of the world: Ecology and conservation. 652 Island Press, Washington, D.C. https://doi.org/10.5822/978-1-61091-008-8

Doerr, J. G., E. J. Degayner, and G. Ith. 2005. Winter habitat selection by Sitka black-tailed deer. The Journal of Wildlife Management 69:322–331.

Farmer, C. J. 2002. Survival and habitat selection of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in a fragmented coastal temperate rainforest. Ph.D. dissertation, State University of New York, College of Environmental Science and Forestry, Syracuse, USA.

Farmer, C. J., D. K. Person, and R. T. Bowyer. 2006. Risk factors and mortality of black-tailed deer in a managed forest landscape. Journal of Wildlife Management 70:1403–1415.

Gelman A. 2008. Scaling regression inputs by dividing by two standard deviations. Statistics in Medicine 27:2865–2873.

Gilbert, S. L. 2015. Environmental drivers of deer population dynamics and spatial selection in Southeast Alaska. University of Alaska Fairbanks, Fairbanks.

Gilbert, S. L., K. J. Hundertmark, M. S. Lindberg, D. K. Person, and M. S. Boyce. 2020. The importance of environmental variability and transient population dynamics for a northern ungulate. Frontiers in Ecology and Evolution 8, 531027. doi:10.3389/fevo.2020.531027.

Gilbert, S. L., K. J. Hundertmark, D. K. Person, M. S. Lindberg, and M. S. Boyce. 2017. Behavioral plasticity in a variable environment: Snow depth and habitat interactions drive deer movement in winter. Journal of Mammalogy 98(1):246–259.

Gillies, C. S., M. Hebblewhite, S. E. Nielsen, M. A. Krawchuk, C. L. Aldridge, J. L. Frair, D. J. Saher, C. E. Stevens, and C. L. Jerde. 2006. Application of random effects to the study of resource selection by animals. Journal of Animal Ecology 75:887–898.

Grunewald, T., Y. Buhler, and M. Lehning. 2014. Elevation dependency of mountain snow depth. The Cryosphere 8:2381–2394.

Hanley, T. A. 1984. Relationships between Sitka black-tailed deer and their habitat. USDA Pacific Northwest Research Station General Technical Report PNW-GTR-168.

Hanley, T. A. 1993. Balancing economic development, biological conservation, and human culture: the Sitka black-tailed *Odocoileus hemionus sitkensis* deer as an ecological indicator. Biological Conservation 66:61–67.

Hanley, T. A. and C. L. Rose 1987. Influence of overstory on snow depth and density in hemlock-spruce stands: implications for management of deer habitat in southeastern Alaska. Research Note PNW-RN-459. Pacific Northwest Research Station, U. S. Forest Service, U. S. Department of Agriculture.

Hanley, T. A., C. T. Robbins, and D. E. Spalinger. 1989. Forest habitats and the nutritional ecology of Sitka black-tailed deer: A research synthesis with implications for forest management. U.S. Forest Service General Technical Report PNW-GTR-230, Portland, Oregon, USA.

Hanley, T. A., M. H. McClellan, J. C. Barnard, and M. A. Friberg. 2013. Precommercial thinning: implications of early results from the Tongass-Wide Young-Growth Studies experiments for deer habitat in Southeast Alaska. US Department of Agriculture, Forest Service, Pacific Northwest Research Station Research Paper PNW-RP-593, Portland, Oregon.

Hijmans, R. J. 2020. Raster: Geographic data analysis and modeling. R package, version 3.3-13. <https://CRAN.R-project.org/package=raster> (Accessed 15 June 2021)

Hosmer, B. F. and S. L. Lemeshow. 2000. Applied logistic regression. Wiley Interscience. New York, USA.

Hovey, F. W., and A. S. Harestad. 1992. Estimating effects of snow on shrub availability for black-tailed deer in southwestern British Columbia. Wildlife Society Bulletin 20(3):308–313.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Johnson, C. J., S. E. Nielsen, E. H. Merrill, T. L. McDonald, and M. S. Boyce. 2006. Resource selection functions based on use-availability data: theoretical motivation and evaluation methods. The Journal of Wildlife Management 70:347–357.

Kirchhoff, M. D., and J. W. Schoen. 1987. Forest cover and snow: Implications for deer habitat in Southeast Alaska. The Journal of Wildlife Management 51:28–33.

Klein, D. R., and S. T. Olsen. 1960. Natural mortality patterns of deer in Southeast Alaska. The Journal of Wildlife Management 24(1):80–88.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald and W. P. Erickson. 2002. Resource selection by animals: Statistical design and analysis for field studies. Kluwer Academic Publishers, Dodrecht, The Netherlands.

Martin, J. R. 1989. Vegetation and environment in old-growth forests of northern southeast Alaska: A plant association classification. M.S. thesis. Arizona State University, Tempe.

Mazza, R. 2003. Hunter demand for deer on Prince of Wales Island, Alaska: An analysis of influencing factors. U.S. Forest Service General Technical Report PNW-GTR-581.

Mcloughlin, P. D., D. W. Morris, D. Fortin, E. Vander Wal, and A. L. Contasti. 2010. Considering ecological dynamics in resource selection functions. Journal of Applied Ecology 79:4–12.

McNay, R. S. and D. D. Doyle. 1987. Winter habitat selection by black-tailed deer on Vancouver Island: a job completion report. British Columbia Ministry of Environment and Parks and Ministry of Forests and Lands. IWIFR-34, Victoria, B.C.

McNay R. S. and F. L. Bunell. 1994. Behavioral limits to movement: the effect on habitat choices for Columbian black-tailed deer. Proceedings of the XXI International Congress of the International Union of Game Biologists 21(2):295–303. Halifax, Nova Scotia; Canada.

Morris, L. R, K. M. Proffitt, and J. K. Blackburn. 2016. Mapping resource selection functions in wildlife studies: concerns and recommendations. Applied Geography. 76:173–183.

Muff, S., J. Signer, and J. Fieberg. 2019. Accounting for individual-specific variation in habitat-selection studies: Efficient estimation of mixed-effects models using Bayesian or frequentist computation. The Journal of Animal Ecology 89:80–92.

Mysterud, A., and E. Ostbye. 1999. Cover as a habitat element for temperate ungulates: Effects on habitat selection and demography. Wildlife Society Bulletin 27:385–394.

Northrup, J. M., M. B. Hooten, C. R. Anderson Jr., and G. Wittemyer. 2013. Practical guidance on characterizing availability in resource selection functions under a use-availability design. Ecology 94:1456–1463.

Northrup, J. M., C. R. Anderson Jr., and G. Wittemyer. 2015. Quantifying spatial habitat loss from hydrocarbon development through assessing habitat selection patterns of mule deer. Global Change Biology doi:10.1111/gcb.13037.

NWS. 2019. NOWdata – NOAA Online Weather Data. National Weather Service Forecast Office. URL:< https://w2.weather.gov/climate/xmacis.php?wfo=pajk> Accessed 9 September 2019.

Parker, K., C. Robbins, and T. A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. The Journal of Wildlife Management 48:474–488.

Parker, K. L., M. P. Gillingham, T. A. Hanley, and C. T. Robbins. 1999. Energy and protein balance of free-ranging black-tailed deer in a natural forest environment. Wildlife Monographs 143:1–48.

Person, D. K., and T. J. Brinkman. 2013. Succession debt and roads: Short- and long-term effects of timber harvest on a large-mammal predator-prey community in Southeast Alaska. Pages 143–167 [*In*] G. H. Orians, and J. W. Schoen, editors. North Pacific Temperate Rainforests: Ecology & Conservation, Audubon Alaska, Anchorage.

Person, D. K., C. Farmer, P. O'Connor, and J. Doerr. 2009. Habitat use and survivorship of Sitka black-tailed deer in Southeast Alaska: A regional meta-analysis and synthesis. Alaska Department of Fish and Game, Juneau. http://www.adfg.alaska.gov/static/home/library/pdfs/wildlife/research_pdfs/2.13_09_final.pdf

Roberts, D. R., V. Bahn, S. Ciuti, M. S. Boyce, J. Elith, G. Guillers-Arroita, S. Hauenstein, J. J. Lahoz-Monfort, B. Schroder, W. Thuiller, D. I. Warton, B. A. Wintle, F. Hartig, and C. F. Dormann. 2017. Cross-validation strategies for data with temporal, spatial, hierarchical, or phylogenetic structure. Ecography 40:913–929.

Schoen, J. W., and M. D. Kirchhoff. 1983. Food habits of Sitka black-tailed deer in southeastern Alaska. Alaska Department of Fish and Game, Division of Game, Final Report 1 July 1980–30 June 1982, Federal Aid in Wildlife Restoration Job 2.7R, Juneau.

Schoen, J. W., and M. D. Kirchhoff. 1985. Seasonal distribution and home range patterns of Sitka black-tailed deer on Admiralty Island, southeast Alaska. The Journal of Wildlife Management 49:96–103.

Schoen, J. W., and M. D. Kirchhoff. 1990. Seasonal habitat use by Sitka black-tailed deer on Admiralty Island, Alaska. The Journal of Wildlife Management 54:371–378.

Turek M. F., R. F. Schroeder, and R. Wolfe. 1998. Deer hunting patterns, resource populations, and management issues on Prince of Wales Island. Alaska Department of Fish and Game, Division of Subsistence, Juneau.

U.S. Forest Service (USFS). 2016. Tongass National Forest Land and Resource Management Plan. United States Department of Agriculture Forest Service R10-MB-769j, Juneau, Alaska. URL: <https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd527907.pdf> Accessed on 15 June 2021.

Wallmo, O. C., and J. W. Schoen. 1980. Responses of deer to secondary forest succession in southeast Alaska. Forest Science 26:448–462.

White, K. S., G. W. Pendleton, and E. Hood. 2009. Effects of snow on Sitka black-tailed deer browse availability and nutritional carrying capacity in Southeastern Alaska. The Journal of Wildlife Management 73:481–487.

Yeo, J. J., and J. M. Peek. 1992. Habitat selection by female Sitka black-tailed deer in logged forests of southeastern Alaska. The Journal of Wildlife Management 56:253–261.

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Appendix A. Sex, number of deer locations, mean continuous covariate value, and proportion of locations in each landcover class by deer-year.

Table A1. Mean values of continuous covariates and proportional representation of land cover classes during winter (1 January–31 March) for GPS telemetry locations (*n*) of Sitka black-tailed deer, Chichagof Island, Alaska, 2010–2013.

			Mean covariate value				Proportion of deer locations in each land cover class					
Deer ID - Year	Sex	*n*[a]	Elevation[b]	Slope[c]	Edge density[d]	Solar radiation[e]	Unproductive forest	SD4	SD567	Young harvested stand (<15 years)	Old harvested stand (≥ 15 years)	Non-forest
Resident deer												
04 - 2010	F	339	56	11	3	289	0.254	0.723	0.018	0.006	0.000	0.000
06 - 2010	F	324	29	7	7	275	0.272	0.000	0.701	0.000	0.000	0.028
06 - 2011	F	306	32	8	6	261	0.176	0.000	0.781	0.000	0.000	0.042
09 - 2011	F	340	96	13	4	314	0.006	0.685	0.209	0.018	0.006	0.076
14 - 2011	F	244	84	14	7	212	0.176	0.627	0.066	0.102	0.029	0.000
32 - 2011	F	307	57	9	9	175	0.062	0.104	0.580	0.104	0.000	0.150
32 - 2012	F	320	53	12	5	305	0.078	0.878	0.009	0.003	0.000	0.031
35 - 2012	F	342	36	5	5	299	0.237	0.570	0.099	0.000	0.076	0.018
40 - 2013	F	292	32	7	7	282	0.312	0.000	0.685	0.000	0.000	0.003
42 - 2013	M	352	133	15	6	330	0.111	0.449	0.000	0.139	0.287	0.014
Migratory deer												
15 - 2011	F	198	49	9	4	293	0.000	0.515	0.000	0.000	0.480	0.005
16 - 2011	F	296	253	24	3	370	0.000	0.000	0.361	0.483	0.000	0.155
20 - 2011	F	311	198	16	1	203	0.000	0.981	0.000	0.000	0.000	0.019
21 - 2011	F	261	275	25	2	455	0.000	0.023	0.912	0.065	0.000	0.000
22 - 2011	M	314	238	15	0	266	0.000	0.818	0.178	0.000	0.000	0.003
22 - 2012	M	307	215	15	1	248	0.000	0.928	0.049	0.000	0.000	0.023
23 - 2011	F	301	146	12	3	275	0.000	0.585	0.053	0.007	0.000	0.355
24 - 2011	M	273	167	21	2	397	0.000	0.000	0.956	0.000	0.000	0.044
25 - 2011	M	322	149	8	0	341	0.000	1.000	0.000	0.000	0.000	0.000
25 - 2012	M	321	124	9	0	361	0.000	1.000	0.000	0.000	0.000	0.000
26 - 2011	F	307	350	24	3	482	0.020	0.345	0.544	0.007	0.000	0.085
26 - 2012	F	326	122	11	3	292	0.000	0.997	0.000	0.003	0.000	0.000
27 - 2011	F	309	270	30	2	399	0.000	0.841	0.123	0.000	0.036	0.000
29 - 2011	M	297	207	22	2	412	0.000	0.337	0.596	0.030	0.000	0.037
30 - 2011	F	307	304	21	1	231	0.007	0.078	0.915	0.000	0.000	0.000
31 - 2011	F	315	170	17	5	376	0.203	0.298	0.451	0.035	0.000	0.013
41 - 2013	F	375	191	36	7	135	0.003	0.725	0.043	0.123	0.107	0.000
Available points												
		10,000	303	19	4	306	0.145	0.288	0.215	0.068	0.037	0.246

[a] Number of locations; [b] Elevation in meters; [c] Slope in degrees; [d] Edge density in km/km^2; [e] Solar radiation in Watt-Hour/m^2.

Appendix B. Resident and migratory deer resource selection function and cross-validation results for all models considered, in order of model rank as determined by Spearman's Rho.

Table B1. Resident Sitka black-tailed deer RSF competitive model coefficients, 95% upper and lower confidence levels (CI) and *k*-fold cross-validation results by mean rho value. Models listed in order of predictive capability with top model having highest predictive ability. Chichagof Island, Alaska, 2010–2013.

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 year)	Old harvested stand (≥ 15 year)	All POG forest[e]	All harvested stands[f]	Mean rho
76[g]	−17.00 (−24.23, 9.78)		0.38 (−0.17, 0.93)	−0.83 (−2.06, 0.40)	1.25 (−0.02, 2.51)					1.73 (0.88, 2.58)	−0.21 (−0.72, 0.29)	0.92
71	−17.37 (−24.20, −10.54)	−0.01 (−1.06, 1.04)	0.40 (−0.16, 0.97)	−0.71 (−2.00, 0.59)	1.29 (0.02, 2.56)					1.73 (0.87, 2.59)	−0.23 (−0.74, 0.29)	0.90
7	−16.84 (−23.91, −9.76)		0.40 (−0.13, 0.94)	−0.76 (−2.00, 0.47)	1.71 (0.29, 3.13)	0.27 (−2.12, 2.65)	0.95 (−0.54, 2.44)	−0.40 (−2.02, 1.21)	−4.39 (−11.69, 2.91)			0.90
16	−17.31 (−24.78, −9.83)			−0.83 (−2.10, 0.45)	1.83 (0.42, 3.24)	0.34 (−1.98, 2.66)	1.01 (−0.52, 2.55)	−0.21 (−1.74, 1.32)	−4.04 (−10.98, 2.91)			0.90
87	−16.98 (−24.03, −9.93)	0.14 (−0.78, 1.06)			1.40 (0.14, 2.67)					1.79 (0.9, 2.68)	−0.04 (−0.48, 0.41)	0.89
92	−16.48 (−23.94, −9.02)				1.34 (0.07, 2.60)					1.8 (0.92, 2.68)	−0.02 (−0.46, 0.41)	0.89
78	−16.72 (−23.34, −10.11)	0.21 (−0.74, 1.16)	0.44 (−0.17, 1.05)		1.30 (0.03, 2.57)					1.75 (0.91, 2.59)	−0.10 (−0.55, 0.35)	0.89
86	−16.09 (−23.18, −9.00)		0.40 (−0.18, 0.99)		1.23 (−0.04, 2.50)					1.76 (0.93, 2.59)	−0.08 (−0.52, 0.37)	0.89
2	−17.40 (−23.86, −10.95)	0.08 (−1.08, 1.24)	0.42 (−0.13, 0.97)	−0.68 (−1.94, 0.58)	1.75 (0.32, 3.19)	0.26 (−2.07, 2.59)	0.86 (−0.73, 2.46)	−0.44 (−2.01, 1.12)	−4.68 (−12.33, 2.97)			0.89
48	−17.57 (−24.02, −11.13)	0.10 (−1.04, 1.24)	0.41 (−0.13, 0.95)	−0.67 (−1.98, 0.64)	1.41 (0.06, 2.76)	0.01 (−2.00, 2.02)	0.51 (−1.35, 2.36)				−0.21 (−0.72, 0.30)	0.89
53	−17.03 (−24.12, −9.95)		0.38 (−0.14, 0.91)	−0.75 (−2.04, 0.53)	1.33 (−0.01, 2.66)	−0.01 (−2.03, 2.01)	0.55 (−1.23, 2.33)				−0.19 (−0.70, 0.31)	0.89
77	−17.53 (−24.77, −10.29)	−0.09 (−1.12, 0.95)		−0.79 (−2.16, 0.59)	1.39 (0.14, 2.64)					1.78 (0.9, 2.67)	−0.15 (−0.63, 0.34)	0.89

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 year)	Old harvested stand (≥ 15 year)	All POG forest[e]	All harvested stands[f]	Mean rho
8	−17.68 (−24.60, −10.76)	0.01 (−1.12, 1.15)		−0.78 (−2.11, 0.54)	1.87 (0.46, 3.28)	0.36 (−1.90, 2.61)	0.94 (−0.70, 2.58)	−0.25 (−1.73, 1.24)				0.88
55	−16.36 (−22.24, −10.49)	0.25 (−0.86, 1.35)	0.44 (−0.15, 1.04)		1.40 (0.05, 2.74)	0.02 (−1.98, 2.02)	0.53 (−1.30, 2.37)				−0.10 (−0.56, 0.35)	0.88
63	−15.58 (−22.15, −9.00)		0.40 (−0.16, 0.97)		1.29 (−0.05, 2.63)	0.00 (−2.00, 2.00)	0.60 (−1.14, 2.34)				−0.07 (−0.52, 0.38)	0.88
85	−17.31 (−24.89, −9.74)			−0.88 (−2.15, 0.40)	1.35 (0.09, 2.61)					1.78 (0.9, 2.67)	−0.14 (−0.61, 0.33)	0.88
54	−17.81 (−24.72, −10.90)	0.03 (−1.09, 1.15)		−0.76 (−2.13, 0.61)	1.50 (0.18, 2.82)	0.06 (−1.90, 2.03)	0.55 (−1.35, 2.46)				−0.13 (−0.62, 0.36)	0.88
62	−17.45 (−24.93, −9.98)			−0.8 (−2.11, 0.52)	1.42 (0.10, 2.74)	0.03 (−1.95, 2.02)	0.59 (−1.24, 2.42)				−0.12 (−0.59, 0.36)	0.88
69	−16.02 (−22.98, −9.06)				1.39 (0.06, 2.72)	0.02 (−1.95, 2.00)	0.63 (−1.16, 2.42)				−0.02 (−0.46, 0.42)	0.88
18	−16.55 (−22.83, −10.26)	0.17 (−0.92, 1.25)			1.84 (0.42, 3.27)	0.31 (−1.99, 2.60)	0.93 (−0.67, 2.54)	−0.17 (−1.73, 1.38)	−4.55 (−12.16, 3.07)			0.88
64	−16.63 (−22.93, −10.34)	0.19 (−0.88, 1.25)			1.49 (0.16, 2.81)	0.04 (−1.93, 2.01)	0.56 (−1.32, 2.45)				−0.04 (−0.49, 0.40)	0.88
9	−16.27 (−22.13, −10.40)	0.22 (−0.91, 1.35)	0.46 (−0.15, 1.06)		1.74 (0.30, 3.17)	0.26 (−2.09, 2.62)	0.89 (−0.67, 2.44)	−0.31 (−1.90, 1.28)	−5.07 (−13.11, 2.98)			0.87
17	−15.47 (−22.01, −8.93)		0.42 (−0.16, 1.00)		1.69 (0.27, 3.10)	0.27 (−2.13, 2.68)	1.01 (−0.41, 2.43)	−0.26 (−1.94, 1.42)	−4.78 (−12.65, 3.09)			0.87
32	−16.62 (−23.23, −10.01)	0.18 (−0.8, 1.16)	0.45 (−0.17, 1.07)		1.62 (0.28, 2.95)			−0.31 (−1.81, 1.19)	−5.17 (−13.1, 2.77)	2.06 (1.28, 2.85)		0.87
41	−16.89 (−23.94, −9.85)	0.12 (−0.83, 1.07)			1.73 (0.40, 3.06)			−0.18 (−1.68, 1.32)	−4.76 (−12.52, 3.00)	2.12 (1.32, 2.92)		0.87
40	−15.99 (−23.04, −8.93)		0.43 (−0.17, 1.02)		1.58 (0.25, 2.90)			−0.28 (−1.85, 1.29)	−4.84 (−12.62, 2.95)	2.10 (1.33, 2.87)		0.87

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 year)	Old harvested stand (≥ 15 year)	All POG forest[e]	All harvested stands[f]	Mean rho
25	−17.21 (−24.05, −10.36)	−0.02 (−1.09, 1.04)	0.42 (−0.16, 0.99)	−0.72 (−1.96, 0.53)	1.61 (0.28, 2.95)			−0.48 (−1.98, 1.02)	−4.84 (−12.56, 2.89)	2.05 (1.25, 2.86)		0.87
30	−16.82 (−24.04, −9.59)		0.40 (−0.16, 0.95)	−0.84 (−2.02, 0.34)	1.59 (0.26, 2.93)			−0.47 (−2.01, 1.07)	−4.54 (−11.97, 2.89)	2.08 (1.27, 2.88)		0.87
46	−16.39 (−23.83, −8.95)				1.70 (0.37, 3.02)			−0.15 (−1.69, 1.39)	−4.50 (−12.08, 3.09)	2.16 (1.37, 2.95)		0.86
23	−15.92 (−22.85, −8.99)				1.80 (0.38, 3.21)	0.32 (−2.04, 2.68)	1.06 (−0.41, 2.52)	−0.12 (−1.75, 1.51)	−4.42 (−12.02, 3.19)			0.86
83		−2.71 (−3.77, −1.65)		−0.49 (−1.65, 0.67)	1.25 (0.10, 2.39)					2.00 (1.25, 2.75)	−0.28 (−0.81, 0.26)	0.86
39	−17.18 (−24.76, −9.60)			−0.9 (−2.15, 0.34)	1.71 (0.39, 3.03)			−0.29 (−1.77, 1.19)	−4.23 (−11.42, 2.97)	2.14 (1.34, 2.94)		0.85
31	−17.41 (−24.67, −10.15)	−0.10 (−1.16, 0.95)		−0.81 (−2.14, 0.52)	1.73 (0.42, 3.05)			−0.30 (−1.74, 1.15)	−4.43 (−11.93, 3.07)	2.13 (1.35, 2.91)		0.85
75		−2.49 (−3.55, −1.43)	0.55 (0.06, 1.04)	−0.39 (−1.48, 0.71)	1.17 (0.00, 2.34)					1.96 (1.18, 2.73)	−0.30 (−0.82, 0.21)	0.84
21			0.86 (0.38, 1.34)		2.17 (0.81, 3.53)	0.71 (−1.95, 3.37)	1.63 (0.33, 2.94)	−0.57 (−2.84,1.70)	−4.05 (−13.05, 4.94)			0.83
84		−2.31 (−3.30, −1.33)	0.56 (0.05, 1.07)		1.15 (−0.03, 2.34)					1.95 (1.17, 2.73)	−0.25 (−0.75, 0.25)	0.83
91		−2.51 (−3.49, −1.53)			1.23 (0.07, 2.40)					1.97 (1.20, 2.74)	−0.23 (−0.76, 0.30)	0.79
37		−2.68 (−3.79, −1.57)		−0.50 (−1.63, 0.64)	1.79 (0.58, 3.00)			−0.77 (−2.91, 1.38)	−4.68 (−13.15, 3.80)	2.53 (1.82, 3.24)		0.76
45		−2.49 (−3.52, −1.45)			1.77 (0.54, 3.00)			−0.73 (−2.92, 1.47)	−4.7 (−13.16, 3.77)	2.51 (1.78, 3.24)		0.75
36			0.86 (0.39, 1.33)	−0.69 (−1.34, −0.05)	2.03 (0.79, 3.28)			−0.69 (−2.80, 1.42)	−4.12 (−12.77, 4.53)	2.66 (1.91, 3.41)		0.74

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 year)	Old harvested stand (≥ 15 year)	All POG forest[e]	All harvested stands[f]	Mean rho
61		−2.29 (−3.32, −1.25)	0.54 (0.05, 1.04)		1.25 (−0.02, 2.52)	0.06 (−2.08, 2.20)	0.99 (−0.72, 2.70)				−0.21 (−0.70, 0.27)	0.73
38		−2.31 (−3.33, −1.28)	0.55 (0.03, 1.07)		1.68 (0.43, 2.92)			−0.77 (−2.90, 1.36)	−4.7 (−13.17, 3.77)	2.47 (1.73, 3.20)		0.73
29		−2.47 (−3.57, −1.37)	0.55 (0.06, 1.04)	−0.38 (−1.45, 0.68)	1.69 (0.45, 2.93)			−0.83 (−2.91, 1.26)	−4.69 (−13.12, 3.74)	2.47 (1.72, 3.22)		0.73
52		−2.44 (−3.54, −1.35)	0.54 (0.06, 1.01)	−0.30 (−1.35, 0.74)	1.26 (0.01, 2.52)	0.07 (−2.07, 2.22)	0.98 (−0.73, 2.69)				−0.27 (−0.76, 0.23)	0.72
82			0.88 (0.41, 1.35)	−0.70 (−1.36, −0.04)	1.47 (0.27, 2.68)					2.10 (1.30, 2.91)	−0.25 (−0.74, 0.25)	0.72
60		−2.66 (−3.75, −1.56)		−0.40 (−1.50, 0.70)	1.35 (0.11, 2.58)	0.11 (−2.03, 2.25)	1.04 (−0.66, 2.73)				−0.23 (−0.76, 0.29)	0.71
68		−2.48 (−3.52, −1.45)			1.32 (0.07, 2.57)	0.07 (−2.08, 2.22)	1.03 (−0.66, 2.73)				−0.19 (−0.71, 0.32)	0.68
6		−2.42 (−3.56, −1.29)	0.53 (0.05, 1.01)	−0.30 (−1.32, 0.72)	1.84 (0.49, 3.20)	0.50 (−2.16, 3.16)	1.58 (0.24, 2.91)	−0.76 (−2.98, 1.47)	−4.62 (−13.4, 4.17)			0.65
44			0.87 (0.39, 1.35)		2.04 (0.78, 3.29)			−0.62 (−2.75, 1.51)	−4.13 (−12.8, 4.53)	2.64 (1.88, 3.39)		0.65
15		−2.27 (−3.35, −1.20)	0.53 (0.03, 1.03)		1.83 (0.47, 3.20)	0.49 (−2.17, 3.15)	1.59 (0.27, 2.91)	−0.71 (−2.99, 1.57)	−4.62 (−13.47, 4.23)			0.64
14		−2.62 (−3.76, −1.47)		−0.41 (−1.48, 0.66)	1.96 (0.62, 3.29)	0.57 (−2.09, 3.23)	1.67 (0.34, 3.00)	−0.69 (−3.00, 1.63)	−4.67 (−13.53, 4.18)			0.64
22		−2.45 (−3.54, −1.37)			1.93 (0.57, 3.29)	0.52 (−2.15, 3.20)	1.66 (0.34, 2.97)	−0.66 (−3.02, 1.70)	−4.67 (−13.51, 4.17)			0.60
89				−0.69 (−1.30, −0.07)	1.67 (0.48, 2.87)					2.26 (1.49, 3.03)	−0.08 (−0.59, 0.43)	0.57
43				−0.69 (−1.30, −0.08)	2.26 (1.05, 3.47)			−0.35 (−2.46, 1.75)	−3.72 (−12.43, 4.98)	2.84 (2.16, 3.53)		0.55

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 year)	Old harvested stand (≥ 15 year)	All POG forest[e]	All harvested stands[f]	Mean rho
13			0.86 (0.38, 1.33)	−0.66 (−1.3, −0.03)	2.17 (0.81, 3.52)	0.73 (−1.93, 3.39)	1.66 (0.34, 2.97)	−0.64 (−2.91, 1.62)	−4.06 (−13.04, 4.91)			0.50
59			0.88 (0.40, 1.35)	−0.67 (−1.32, −0.02)	1.55 (0.26, 2.84)	0.26 (−1.90, 2.42)	1.02 (−0.69, 2.72)				−0.22 (−0.7, 0.26)	0.47
20				−0.66 (−1.25, −0.06)	2.42 (1.08, 3.77)	0.98 (−1.61, 3.56)	1.87 (0.53, 3.22)	−0.28 (−2.55, 1.98)	−3.62 (−12.6, 5.35)			0.37
66				−0.65 (−1.25, −0.05)	1.76 (0.48, 3.04)	0.45 (−1.65, 2.55)	1.18 (−0.53, 2.89)				−0.05 (−0.54, 0.44)	0.37
67			0.88 (0.41, 1.35)		1.55 (0.25, 2.86)	0.24 (−1.92, 2.40)	0.99 (−0.70, 2.69)				−0.17 (−0.64, 0.31)	0.36
90			0.89 (0.41, 1.36)		1.48 (0.26, 2.70)					2.08 (1.27, 2.90)	−0.19 (−0.68, 0.29)	NA

[a] Elevation in meters; [b] Slope in degrees; [c] Edge density in km/km^2; [d] Solar radiation in Watt–Hour/m^2; [e] SD4 and SD567 grouped; [f] Young and old cuts grouped; [g] Top model.

Table B2. Migratory Sitka black−tailed deer RSF competitive model coefficients, 95% upper and lower confidence levels (CI) and k-fold cross-validation results by mean rho value. Models listed in order of predictive capability with top model having highest predictive ability. Chichagof Island, Alaska, 2010–2013.

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 years)	Old harvested stand (≥15 years)	All POG forest[e]	All harvested stands[f]	Mean rho
55[g]	−1.96 (−3.96, 0.05)	0.09 (−0.89, 1.08)	−2.00 (−3.18, −0.83)		−8.08 (−14.83, −1.32)	2.66 (0.58, 4.75)	0.77 (−1.26, 2.81)				−0.13 (−0.71, 0.44)	0.90
71	−1.95 (−3.80, −0.10)	−0.52 (−1.77, 0.73)	−2.01 (−3.16, −0.85)	0.54 (−0.51, 1.59)	−8.14 (−14.84, −1.45)					3.23 (1.85, 4.60)	−0.16 (−0.74, 0.42)	0.86
76	−2.08 (−3.86, −0.31)		−1.94 (−3.02, −0.86)	−0.03 (−1.15, 1.10)	−8.02 (−14.68, −1.37)					3.11 (1.81, 4.41)	−0.17 (−0.77, 0.43)	0.86
86	−1.71 (−3.53, 0.11)		−1.98 (−3.06, −0.90)		−8.11 (−14.68, −1.53)					3.19 (1.90, 4.47)	−0.11 (−0.73, 0.50)	0.86
63	−1.69 (−3.55, 0.16)		−1.97 (−3.05, −0.88)		−8.07 (−14.69, −1.45)	2.64 (0.58, 4.70)	0.85 (−1.15, 2.85)				−0.08 (−0.69, 0.53)	0.85
78	−1.87 (−3.78, 0.04)	0.01 (−1.06, 1.08)	−2.07 (−3.29, −0.86)		−8.17 (−14.87, −1.46)					3.25 (1.89, 4.62)	−0.15 (−0.73, 0.43)	0.85
48	−2.10 (−4.08, −0.12)	−0.40 (−1.57, 0.77)	−1.97 (−3.08, −0.86)	0.53 (−0.54, 1.60)	−8.03 (−14.77, −1.29)	2.63 (0.52, 4.75)	0.72 (−1.30, 2.75)				−0.15 (−0.73, 0.43)	0.85
53	−2.08 (−3.91, −0.24)		−1.93 (−3.00, −0.86)	−0.09 (−1.29, 1.12)	−7.99 (−14.69, −1.29)	2.61 (0.52, 4.69)	0.73 (−1.25, 2.72)				−0.14 (−0.75, 0.46)	0.84
25	−1.67 (−3.19, −0.16)	−0.56 (−1.82, 0.70)	−2.02 (−3.17, −0.86)	0.49 (−0.56, 1.55)	−7.99 (−14.66, −1.32)			−0.61 (−3.10, 1.89)	−10.31 (−17.28, −3.34)	4.34 (2.74, 5.95)		0.80
60		−0.75 (−1.81, 0.32)		0.53 (−0.57, 1.62)	−8.18 (−14.81, −1.55)	2.75 (0.78, 4.73)	1.10 (−0.56, 2.76)				−0.10 (−0.74, 0.53)	0.79
30	−1.86 (−3.41, −0.32)		−1.95 (−3.02, −0.87)	−0.08 (−1.21, 1.04)	−7.58 (−14.47, −0.70)			−0.72 (−3.28, 1.83)	−10.21 (−17.29, −3.14)	4.17 (2.64, 5.70)		0.79
2	−1.79 (−3.40, −0.18)	−0.45 (−1.61, 0.72)	−1.98 (−3.09, −0.86)	0.48 (−0.60, 1.55)	−7.77 (−14.62, −0.93)	3.80 (1.44, 6.17)	1.93 (−0.08, 3.94)	−0.46 (−2.94, 2.01)	−10.23 (−17.26, −3.2)			0.79
9	−1.65 (−3.30, −0.01)	0.04 (−0.95, 1.03)	−2.00 (−3.18, −0.82)		−7.75 (−14.54, −0.97)	3.86 (1.54, 6.17)	2.00 (−0.02, 4.02)	−0.39 (−2.84, 2.06)	−9.93 (−17.26, −2.59)			0.78
7	−1.85 (−3.44, −0.26)		−1.94 (−3.01, −0.87)	−0.15 (−1.35, 1.05)	−7.44 (−14.51, −0.36)	3.74 (1.43, 6.05)	1.86 (−0.14, 3.87)	−0.49 (−2.97, 1.98)	−10.15 (−17.28, −3.03)			0.78
17	−1.47 (−3.10, 0.16)		−1.97 (−3.06, −0.88)		−7.36 (−14.38, −0.34)	3.82 (1.55, 6.09)	2.02 (−0.03, 4.06)	−0.43 (−3.04, 2.18)	−9.83 (−17.37, −2.30)			0.77
40	−1.48 (−3.07, 0.10)		−1.98 (−3.06, −0.89)		−7.52 (−14.36, −0.68)			−0.66 (−3.34, 2.03)	−9.83 (−17.33, −2.33)	4.27 (2.77, 5.77)		0.77

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 years)	Old harvested stand (≥15 years)	All POG forest[e]	All harvested stands[f]	Mean rho
32	−1.57 (−3.14, −0.01)	−0.04 (−1.11, 1.04)	−2.08 (−3.29, −0.86)		−7.90 (−14.52, −1.29)			−0.53 (−2.99, 1.93)	−9.95 (−17.23, −2.67)	4.37 (2.82, 5.92)		0.77
21			−1.82 (−2.87, −0.77)		−6.66 (−13.71, 0.39)	3.87 (1.68, 6.06)	2.22 (0.56, 3.87)	−0.07 (−2.36, 2.22)	−9.15 (−15.71, −2.60)			0.76
61		−0.42 (−1.37, 0.53)	−1.94 (−3.12, −0.75)		−7.91 (−14.79, −1.03)	2.74 (0.80, 4.67)	1.07 (−0.66, 2.80)				0.00 (−0.57, 0.57)	0.75
67			−1.78 (−2.85, −0.71)		−7.71 (−14.13, −1.29)	2.70 (0.68, 4.73)	1.02 (−0.69, 2.73)				0.00 (−0.51, 0.50)	0.75
84		−0.48 (−1.48, 0.52)	−2.02 (−3.25, −0.79)		−8.02 (−14.78, −1.25)					3.31 (2.15, 4.47)	−0.02 (−0.60, 0.56)	0.74
75		−1.02 (−2.17, 0.14)	−1.98 (−3.15, −0.80)	0.42 (−0.61, 1.44)	−8.01 (−14.80, −1.21)					3.38 (2.19, 4.58)	0.01 (−0.56, 0.58)	0.74
82			−1.74 (−2.80, −0.68)	−0.21 (−1.26, 0.85)	−7.78 (−14.30, −1.27)					3.41 (2.20, 4.62)	0.04 (−0.47, 0.55)	0.74
38		−0.44 (−1.47, 0.58)	−2.07 (−3.28, −0.86)		−7.44 (−13.96, −0.92)			−0.46 (−3.14, 2.22)	−9.24 (−16.18, −2.30)	4.44 (3.07, 5.81)		0.74
15		−0.39 (−1.36, 0.58)	−1.98 (−3.15, −0.81)		−7.19 (−13.95, −0.44)	3.93 (1.77, 6.10)	2.27 (0.55, 3.99)	−0.25 (−2.84, 2.33)	−9.26 (−16.18, −2.34)			0.73
29		−0.97 (−2.16, 0.21)	−2.02 (−3.18, −0.87)	0.40 (−0.63, 1.42)	−7.44 (−14.01, −0.87)			−0.35 (−3.00, 2.30)	−9.30 (−16.25, −2.36)	4.54 (3.13, 5.95)		0.73
13			−1.81 (−2.86, −0.76)	−0.28 (−1.42, 0.86)	−6.71 (−13.76, 0.33)	4.05 (1.85, 6.25)	2.33 (0.68, 3.98)	0.10 (−2.17, 2.37)	−9.02 (−15.71, −2.33)			0.73
52		−0.94 (−2.02, 0.15)	−1.92 (−3.06, −0.78)	0.41 (−0.61, 1.43)	−7.87 (−14.78, −0.96)	2.80 (0.83, 4.78)	1.14 (−0.56, 2.85)				0.03 (-0.53, 0.60)	0.72
54	−2.13 (−4.02, −0.24)	−0.24 (−1.37, 0.89)		0.72 (−0.50, 1.94)	−8.28 (−14.80, −1.76)	2.48 (0.43, 4.53)	0.59 (−1.33, 2.51)				−0.27 (−0.83, 0.30)	0.72
14		−0.71 (−1.80, 0.39)		0.51 (−0.59, 1.60)	−7.65 (−14.30, −0.99)	3.96 (1.71, 6.21)	2.26 (0.53, 3.99)	−0.78 (−3.84, 2.28)	−9.62 (−16.44, −2.80)			0.72
6		−0.89 (−2.01, 0.23)	−1.96 (−3.09, −0.84)	0.38 (−0.64, 1.41)	−7.18 (−13.96, −0.41)	4.02 (1.81, 6.23)	2.35 (0.63, 4.07)	−0.18 (−2.79, 2.43)	−9.35 (−16.28, −2.42)			0.72
77	−1.96 (−3.71, −0.22)	−0.33 (−1.54, 0.88)		0.77 (−0.43, 1.96)	−8.37 (−14.85, −1.89)					3.04 (1.74, 4.33)	−0.28 (−0.84, 0.28)	0.72
59			−1.76 (−2.83, −0.69)	−0.27 (−1.39, 0.85)	−7.66 (−14.23, −1.10)	2.85 (0.83, 4.87)	1.10 (−0.62, 2.81)				0.05 (−0.45, 0.56)	0.71

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 years)	Old harvested stand (≥15 years)	All POG forest[e]	All harvested stands[f]	Mean rho
36			−1.79 (−2.83, −0.75)	−0.22 (−1.29, 0.85)	−6.98 (−13.84, −0.12)			−0.04 (−2.33, 2.25)	−8.99 (−15.68, −2.30)	4.54 (3.18, 5.90)		0.71
22		−0.13 (−0.99, 0.72)			−7.61 (−14.24, −0.97)	3.86 (1.66, 6.06)	2.19 (0.47, 3.92)	−0.81 (−3.77, 2.14)	−9.51 (−16.33, −2.69)			0.70
68		−0.17 (−0.99, 0.65)			−8.15 (−14.77, −1.53)	2.68 (0.73, 4.62)	1.04 (−0.64, 2.72)				−0.13 (−0.75, 0.48)	0.69
83		−0.78 (−1.91, 0.34)		0.58 (−0.50, 1.66)	−8.30 (−14.82, −1.79)					3.3 (2.15, 4.46)	−0.13 (−0.77, 0.51)	0.69
69	−1.52 (−3.26, 0.23)				−8.37 (−14.78, −1.97)	2.50 (0.48, 4.52)	0.77 (−1.11, 2.66)				−0.22 (−0.81, 0.37)	0.69
37		−0.74 (−1.90, 0.42)		0.56 (−0.53, 1.64)	−7.91 (−14.36, −1.45)			−1.01 (−4.19, 2.16)	−9.59 (−16.43, −2.75)	4.48 (3.03, 5.92)		0.68
62	−1.97 (−3.73, −0.21)			0.02 (−1.25, 1.29)	−8.33 (−14.80, −1.87)	2.50 (0.45, 4.55)	0.66 (−1.23, 2.55)				−0.27 (−0.85, 0.31)	0.68
64	−1.96 (−3.86, −0.07)	0.36 (−0.48, 1.19)			−8.27 (−14.82, −1.73)	2.45 (0.43, 4.47)	0.60 (−1.32, 2.53)				−0.27 (−0.83, 0.29)	0.66
31	−1.69 (−3.14, −0.24)	−0.37 (−1.58, 0.84)		0.71 (−0.50, 1.91)	−8.19 (−14.71, −1.66)			−1.06 (−3.70, 1.58)	−10.23 (−17.1, −3.36)	4.13 (2.63, 5.63)		0.66
8	−1.83 (−3.39, −0.27)	−0.29 (−1.41, 0.84)		0.66 (−0.57, 1.89)	−8.00 (−14.70, −1.30)	3.63 (1.35, 5.92)	1.79 (−0.09, 3.67)	−0.88 (−3.45, 1.70)	−10.17 (−17.1, −3.23)			0.65
45		−0.13 (−1.03, 0.77)			−7.87 (−14.28, −1.46)			−1.06 (−4.15, 2.04)	−9.47 (−16.31, −2.62)	4.36 (2.97, 5.75)		0.65
85	−1.92 (−3.59, −0.25)			0.09 (−1.07, 1.25)	−8.38 (−14.80, −1.95)					3.01 (1.76, 4.26)	−0.30 (−0.88, 0.28)	0.63
39	−1.72 (−3.21, −0.23)			0.03 (−1.12, 1.19)	−8.00 (−14.68, −1.32)			−1.11 (−3.77, 1.54)	−10.12 (−17.08, −3.15)	4.05 (2.59, 5.51)		0.62
23	−1.32 (−2.89, 0.26)				−7.81 (−14.62, −1.00)	3.67 (1.44, 5.90)	1.94 (0.03, 3.85)	−0.90 (−3.66, 1.86)	−9.77 (−17.12, −2.43)			0.61
18	−1.67 (−3.25, −0.09)	0.30 (−0.53, 1.13)			−7.95 (−14.59, −1.30)	3.60 (1.38, 5.81)	1.80 (−0.07, 3.67)	−0.86 (−3.39, 1.68)	−9.85 (−17.00, −2.70)			0.61
66				−0.23 (−1.38, 0.92)	−7.95 (−14.25, −1.65)	2.72 (0.75, 4.70)	1.02 (−0.64, 2.68)				−0.08 (−0.61, 0.45)	0.61
91		−0.17 (−1.04, 0.70)			−8.27 (−14.77, −1.77)					3.23 (2.10, 4.35)	−0.17 (−0.79, 0.46)	0.60

ID	Elevation[a]	Slope[b]	Edge density[c]	Solar radiation[d]	Unproductive forest	SD4 forest	SD567 forest	Young harvested stand (<15 years)	Old harvested stand (≥15 years)	All POG forest[e]	All harvested stands[f]	Mean rho
16	−1.76 (−3.31, −0.21)			−0.04 (−1.30, 1.21)	−7.85 (−14.70, −1.00)	3.62 (1.35, 5.90)	1.80 (−0.09, 3.68)	−0.89 (−3.45, 1.67)	−10.08 (−17.09, −3.07)			0.60
87	−1.83 (−3.62, −0.05)	0.31 (−0.60, 1.22)			−8.38 (−14.87, −1.90)					3.03 (1.74, 4.31)	−0.29 (−0.84, 0.27)	0.60
92	−1.49 (−3.18, 0.20)				−8.43 (−14.78, −2.08)					3.06 (1.83, 4.29)	−0.26 (−0.85, 0.34)	0.59
20				−0.24 (−1.40, 0.93)	−7.32 (−14.17, −0.47)	3.90 (1.70, 6.09)	2.19 (0.56, 3.83)	−0.48 (−3.05, 2.09)	−9.24 (−15.75, −2.74)			0.57
46	−1.29 (−2.81, 0.23)				−7.97 (−14.61, −1.33)			−1.12 (−3.96, 1.72)	−9.76 (−17.08, −2.44)	4.12 (2.70, 5.54)		0.54
41	−1.55 (−3.04, −0.07)	0.26 (−0.66, 1.18)			−8.15 (−14.61, −1.68)			−1.02 (−3.60, 1.56)	−9.87 (−16.96, −2.78)	4.09 (2.66, 5.53)		0.54
43				−0.17 (−1.24, 0.91)	−7.53 (−14.19, −0.88)			−0.68 (−3.34, 1.98)	−9.20 (−15.71, −2.70)	4.36 (3.02, 5.69)		0.53
89				−0.16 (−1.22, 0.90)	−8.04 (−14.27, −1.81)					3.25 (2.11, 4.39)	−0.10 (−0.64, 0.44)	0.53
44			−1.81 (−2.84, −0.77)		−6.96 (−13.85, −0.08)			−0.20 (−2.50, 2.10)	−9.14 (−15.7, −2.58)	4.39 (3.05, 5.74)		NA
90			−1.76 (−2.81, −0.71)		−7.83 (−14.21, −1.46)					3.29 (2.08, 4.50)	−0.01 (−0.52, 0.49)	NA

[a] Elevation in meters; [b] Slope in degrees; [c] Edge density in km/km^2; [d] Solar radiation in Watt−Hour/m^2; [e] SD4 and SD567 grouped; [f] Young and old cuts grouped, [g] Top model.