EVALUATING AMERICAN MARTEN HABITAT QUALITY USING AIRBORNE LIGHT DETECTION AND RANGING (LIDAR) DATA[1]

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CHAPTER 1: INDIVIDUAL DETECTION OF COARSE WOODY DEBRIS USING AIRBORNE LIDAR

SUMMARY OF FINDINGS

Coarse woody debris (CWD) is an essential component of forest ecosystems that provides habitat for diverse species, functions in water and nutrient cycling, and can be a potential surface fuel in wildfires. CWD detection and mapping would enhance forestry and wildlife research and management but passive remote sensing technologies cannot provide information on features beneath forest canopy, while field-based CWD inventories are not practical for mapping CWD over large areas. Airborne light detecting and ranging (LiDAR) is a remote sensing technology that provides detailed information on three-dimensional vegetation structure that could overcome limitations of field-based inventories. Our objectives were to evaluate whether airborne LiDAR could be used to detect individual pieces of CWD. We measured 1,968 pieces of CWD at 189 field plots from 2015 to 2016. We acquired high-density (~24 first returns/m^2) LiDAR data in 2014 and filtered out canopy and sub-canopy returns using a height threshold based on field measurements of CWD and used height-filtered data to determine which field-measured pieces of CWD were visible in the resulting point cloud. CWD pieces detected constituted 50% of plot CWD volume, and there was a strong, positive correlation between total plot CWD volume and volume of detected pieces ($r = 0.96$). Overall, we detected 23% of the individual pieces of CWD we measured. Large pieces of CWD were most likely to be detected, with the majority of pieces ≥30 cm diameter or ≥13.9 m long detected. Canopy density, shrub density, and forest type did not influence detection probability. CWD detection rates increased from 1 pulses/m^2 to 16 pulses/m^2, and CWD detection rate was constant from 16 pulses/m^2 to 24 pulses/m^2. Our results demonstrate that airborne LiDAR can be used to detect CWD. LiDAR-based detection and mapping of CWD will be most useful for applications that focus on larger and longer pieces of CWD or applications focused on total CWD volume.

CHAPTER 2: MEASURING FOREST CHARACTERISTICS USING LIDAR: HOW WELL DO LIDAR-DERIVED REGRESSION MODELS PERFORM WHEN APPLIED TO NEW DATA?

SUMMARY OF FINDINGS

Light detection and ranging (LiDAR) is an active remote sensing technology that has been used increasingly to measure topographic and vegetative structure for forestry and wildlife applications. Measurement of vegetation characteristics that cannot be measured directly from LiDAR data is typically accomplished through LiDAR forest inventory modeling, in which a statistical model is developed that relates LiDAR-derived explanatory variables to field-measured response

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variables. The successful use of LiDAR forest inventory models for forestry and wildlife applications relies on development of statistical models that provide accurate and precise estimates of the response variables of interest, particularly when the model is imputed across the landscape. Because the goal of LiDAR forest inventory modeling is generally to identify the best statistical model for prediction from many potential candidate models, investigators have often used exhaustive model-fitting techniques to select final models. Furthermore, not all investigators have adequately addressed potential issues associated with overfitting and collinearity while developing LiDAR forest inventory models. Our objectives were to evaluate how well LiDAR forest inventory models created with multiple regression techniques performed when used to make predictions on new data. We created regression models for 5 response variables: basal area, average tree diameter, maximum tree diameter, quadratic mean tree diameter, and tree density. We used cross validation and bootstrapping techniques to evaluate model performance on new data. Our results demonstrated that models generally performed well on new data, that including collinear variables did not substantially reduce model performance relative to models without collinear variables, and that model performance on new data varied among response variables. Taken together, our results suggest that LiDAR forest inventory models are likely to perform well when imputed across the landscape of interest, but also highlight the importance of including explicit testing of models using new data or internal validation techniques during model development phases.

CHAPTER 3: SPATIAL AND ANNUAL VARIATION IN HARVEST MORTALITY RISK FOR AMERICAN MARTENS

SUMMARY OF FINDINGS

Understanding animal-habitat relationships is a common focus of ecological research. Most studies of animal habitat selection focus on describing characteristics of sites used by animals relative to availability. Although these studies have improved our understanding of animal-habitat relationships, descriptive habitat analyses based on animal presence generally do not consider survival or reproductive output of the population and are unable to distinguish between the relative qualities of habitats used by different individuals within a population. Differences in mortality risk or reproductive success among areas of otherwise similar habitat can result in functional differences in habitat quality. Harvest is a major source of mortality for many wildlife species. Our objectives were to investigate spatial and annual variation in harvest mortality risk for American martens for application to a fitness-based understanding of habitat quality. We used data from radio-collared martens and harvest statistics to test whether harvest risk was influenced by marten age, sex, accessibility to trappers, and harvest levels. Harvest risk was higher for males than females and negatively correlated with average distance from roads. There was a weak positive effect of harvest intensity on harvest risk, but age class did not affect harvest risk. Areas with suitable habitat near roads may function as attractive sink-like habitat due to elevated mortality risk from harvest, while suitable habitat farther from roads may function as source-like habitat and be of higher overall quality. We suggest that spatial variation in harvest mortality risk is an important factor that contributes to population structure, source-sink dynamics, and gene flow.

CHAPTER 4: THE ROLE OF HABITAT STRUCTURE IN PREDATION OF AMERICAN MARTENS BY BOBCATS AND OTHER INTRAGUILD PREDATORS

SUMMARY OF FINDINGS

Intraguild predation occurs in many carnivore communities and can have profound effects on trophic interactions, community structure, and population regulation. Habitat can play an important role in modulating the frequency and outcome of encounters between intraguild predators and intraguild prey. Fine-scale habitat structure can reduce susceptibility of intraguild prey by providing concealment, escape cover, and refugia, or can increase predation risk by impeding detection of potential predators. American martens are small mustelid carnivores that are susceptible to predation by several predator species. Although predation risk is often used to explain habitat selection patterns of martens, there are few direct tests of the role of habitat structure on interactions of martens with their predators. Our objectives were to examine the role that habitat structure plays in mediating interactions between martens and predators. Because bobcats are frequent predators of martens, we focused our analysis primarily on marten-bobcat interactions. We used light detection and ranging (LiDAR) data to measure canopy and understory characteristics and compared characteristics of sites where martens were killed by predators to non-mortality telemetry locations. Sites where martens were killed by bobcats were closer to non-forested habitat and were near more non-forested habitat than non-mortality locations. The structural characteristics and types of non-forested habitats associated with mortality sites varied among carnivore species. Our results provide direct evidence that martens experience elevated mortality risk when in or near non-forested areas without tree canopy, including shrublands, wetlands, and young/regenerating forest.