Chapter 4. Use of LIDAR to determine vegetation vertical distribution in areas of potential black-capped vireo habitat at Fort Hood, Texas

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Abstract: *LI*ght Detection and Ranging (LIDAR) data were used to describe the vertical structure of vegetation in areas of potential habitat for the black-capped vireo (*Vireo atricapillus)* on Fort Hood Military Reservation. Three habitat types were described and mapped using patch polygons that were derived from classification of the LIDAR data: donut, classical and linear. Field data were collected by randomly selecting a set of patch polygons within each of the 3 habitat classes. Preliminary results indicate that 57% of the polygons representing donut habitat were correctly classified. Classical habitat was classified correctly 44% of the time, whereas linear habitat classified correctly only 8% of the time. Classification errors have been attributed to two primary factors. First, the analysis of LIDAR data alone can not yet, and may never be able to identify species composition within the patches, specifically the presence of juniper, a largely non-habitat species for the black-capped vireo. The second source of error was due to the presence of vegetation that resembled classical habitat, with the exception of a higher percentage of tall trees. This vegetation was referred to as "mixed habitat." The initial LIDAR analysis was not geared to identify this fourth habitat type. It is expected that the development of a modified analytical routine to include this additional habitat and to remove juniper (through fusion with high resolution multispectral or comparable imagery) will render higher accuracy levels. In addition to habitat classification based on pre-defined vegetation classes, LIDAR data are being used in combination with black-capped vireo locations collected during the 2002 field season to describe areas occupied by birds. The information generated by these two approaches (pre-defined habitat classes and areas occupied by birds) will be used to develop a predictive habitat model for the species.

Introduction

The black-capped vireo (*Vireo atricapillus)* is a small neotropical migrant whose breeding distribution ranged from southern Kansas through central Oklahoma and Texas into northern Mexico (Graber 1961, Grzybowski 1995, Ekrich et al. 1999). Population declines in historical breeding areas within the United States have been reported (Grzybowski 1995), and population trends in northern Mexico are unknown (Scott and Garton 1991). Black-capped vireos are likely extirpated from Kansas, only occur in 3 small populations in west-central Oklahoma, and are declining in Texas (Grzybowski 1995). Grzybowski (1995) suggested that brood parasitism (mainly attributed to the brown-headed cowbird (*Molothrus ater*)) and habitat fragmentation are the main causes for the species' decline.

Breeding habitat occurs in shrubland areas composed of small, dense thickets of irregular height and distribution (Graber 1961, Grzybowski 1995) often on rocky substrates with shallow soils (Sexton 1990). Specific vegetative components of black-capped vireo habitat vary by region, but are predominantly composed of deciduous species dominated in many areas by oaks (*Quercus* spp.) (Grzybowski 1995). Suitable habitat generally occurs as a transitional stage in ecological succession, becoming unsuitable as the community matures and trees grow into closed-canopy forest (Marshall et al. 1985). Historically, natural disturbances in areas with appropriate substrates presumably generated and maintained suitable black-capped vireo habitat (Benson and Benson 1990, Grzybowski 1995). Grzybowski (1995:5) suggested that significant patches of suitable breeding habitat occurred after fires produced regrowth of fire-adapted species. Marshall et al. (1985) suggested that the best black-capped vireo habitat was generated 10-15 years after fires intense enough to kill Ashe juniper (*Juniperus ashei*). Tazik et al. (1993b) suggested that vireo habitat develops within 5 years after fire on Fort Hood. In the absence of natural fires, prescribed burning has been used as an effective tool for maintaining vireo habitat (O'Neal et al. 1996).

The black-capped vireo was listed as a federally endangered species in 1987 (Ratzlaff 1987). In 1991, the U.S. Fish and Wildlife Service developed a recovery plan for the species which defines criteria and specific actions required for meeting recovery objectives (U.S. Fish and Wildlife Service 1991). According to this plan, in order to remove the species from its endangered status, ≥ 500 breeding pairs must be present and sustainable in each of 6 recovery regions located in Oklahoma (n = 1), Texas (n = 4), and Mexico (n = 1). Actions required to meet these objectives include:

1. Additional research to assess population size and distribution, habitat requirements, and threats;
2. management and maintenance of viable vireo populations by cowbird control and habitat management techniques; and
3. development of monitoring programs to assess vireo population status (U.S. Fish and Wildlife Service 1991).

Fort Hood Military Reservation, Texas sustains the largest population of black-capped vireo under one land management authority (Tazik et al. 1993a). It has been suggested that the black-capped vireo population breeding at Fort Hood represent 18% of the known population in the United States (Tazik et al. 1993b). The U.S. Fish and Wildlife Service issued a Biological Opinion to the Department of Defense (DoD) in 1993 that defined the terms and conditions under which the Army can continue to train while protecting endangered species on Fort Hood (U.S. Fish and Wildlife Service 1993, 2000). Under the terms and conditions of the Biological Opinion, the DoD is required to maintain annual monitoring projects to determine population trends and to update population viability models. Data collected on Fort Hood are used to determine distribution, abundance, productivity, nesting success, population age structure, return rates, and dispersal of vireos on Fort Hood (The Nature Conservancy 2000).

Habitat delineation is an important component of black-capped vireo population management on Fort Hood, because it helps to minimize potential conflicts with military training activities. Efforts to delineate potential black-capped vireo habitat at Fort Hood have been conducted in the past using both traditional field data collection (Tazik et al. 1993b) and remotely sensed data (The Nature Conservancy, Unpublished Data). The use of traditional habitat description using field data has suggested the need for a more efficient approach to habitat delineation. As an alternative, remotely sensed data have been used to address this issue.

Traditionally, remotely sensed data have been used to depict the horizontal distribution of resources and processes, such as vegetation cover and road systems (Means et al. 1999). However, the description of the vertical distribution of the resources (i.e., vegetation structure) using these techniques is limited. LIght Detection and Ranging (LIDAR) is an emerging technology that has been used in forestry to estimate vegetation biomass and cover (Means et al. 1999, Evans et al. 2001, Harding et al. 2001), vegetation structure (Drake et al. 2002) and forest production (Lefsky et al. 2001). However, techniques have not been developed and applied to describe the structure of shrublands. Because of its capability to describe vegetation structure, it was hypothesized that multiple return LIDAR in combination with fieldwork and other remotely sensed data could be used as an alternative method to delineate habitat for black-capped vireo on Fort Hood Military Reservation.

Background

LIDAR Description

Airborne LIDAR data are collected using an scanning laser sensor system, typically flown aboard a rotary or fixed-wing aircraft at elevations of hundreds to a few thousand meters above ground level (AGL). The sensor transmits short laser pulses towards the ground. The incident pulse of energy interacts with the surface, colliding with the various earth features encountered (i.e., ground, trees, etc.) and reflecting back to the sensor, which records the data (Means et al. 1999). Using global positioning system (GPS) and aircraft attitude data from an inertial motion unit (IMU), the returned pulses can be converted into x, y, z coordinates that map terrain and other aboveground features of the earth's surface. Bare (or bald) earth digital terrain models (DTMs) are one of the first products that are typically derived from LIDAR data. These are generated by segmenting the LIDAR point data into ground and non-ground classes, then using these classes to create a raster grid or triangulated irregular network (TIN) from the ground points (Hill et al. 2000). Canopy height is another valuable measurement that can be derived through analysis of LIDAR data (Hill et al. 2000, Dubayah et al. 2001). Several different methods have been applied to estimate canopy height from LIDAR data, including the method used in this study.

Black-capped vireo Habitat

Black-capped vireos breed in scrubby tree growth of the forest-grassland ecotone (Graber

1961). The species has been found in prairie ravines in Kansas, as well as canyons of the Pecos River in western Texas (Graber 1961). Fire and vegetation clearing produces potential habitat for the species. On Fort Hood, black-capped vireos have been located in contiguous patches of shrubland less than 3 m in height that are dominated by shin oak (*Q. sinuata* var. *breviloba*) and flame-leaf sumac (*Rhus lanceolata*) (The Nature Conservancy, unpublished data). Areas occupied by the species have relatively few mature Ashe juniper and honey mesquite (*Prospis glandulosa*). This constitutes a typical habitat for the species and has been identified as "classical habitat" (The Nature Conservancy, unpublished data). Black-capped vireos also occupy vegetation bordering trails created by off-road military vehicle traffic. This habitat type has been described as "linear habitat" and may be the most abundant type due to the extensive network of trails across the installation. Black-capped vireos have also been encountered in areas where heavy equipment (e.g., tanks) maneuver around trees, "trimming" shrubs around these trees. A distinctive characteristic of this type of habitat is the circular shape created by the movement of heavy equipment, hence the name "donut habitat" (The Nature Conservancy, unpublished data).

Study Area

Fort Hood Military Reservation is located in Bell and Coryell counties, Texas within the Crosstimbers and Southern Tallgrass Prairie and the Edwards Plateau Ecoregions (The Nature Conservancy 1997). Broad valleys and steep hills characterize this area and elevations range from 180 to 373 m above sea level (Ribanszky and Zhang 1992). Vegetation in the area consists mainly of shrublands, grasslands, and oak-Ashe juniper (*Quercus* spp.-*Juniperus ashei*) woodlands.

Military training takes place across the entire military installation; however, the western portion of Fort Hood (Fig. 4.1) supports more armored vehicle traffic compared to the eastern portion of the area. Landscape disturbances due to maneuver exercises promote the generation of edge vegetation, and the creation of potential habitat for black-capped vireo. Therefore, the western portion of Fort Hood was selected to assess LIDAR applications to describe the vertical distribution of vegetation. Within this area a 25.89-sq km study area (Fig. 4.1) was selected to represent the primary black-capped vireo habitat types as well as other important environmental components such as erosion and golden-cheeked warbler (*Dendroica chrysoparia*) habitat.

METHODS

LIDAR Data Acquisition

LIDAR images were acquired from TerraPoint LLC™ using the Airborne Laser Topographic Mapping System (ALTMS), originally developed by the Houston Advanced Research Center (HARC) through a NASA-funded project. This system is capable of recording up to four returns from each laser pulse.

Data were acquired during the last week of April 2002 to ensure the presence of leaves on vegetation. Flight lines were flown in an east-west direction at an altitude of 915 meters, providing 1.7-meter point spacing. A minimum overlap of 30% between flight lines assured total coverage. The data were delivered as binary point files in TerraSoild's TerraScan format (TerraScan 1999). The data had been pre-classified using a TerraScan macro that differentiates ground, aboveground feature, and error returns. The area encompassed by each file was 1200 square meters (one square kilometer with a 100-meter buffer). Each data record consisted of the x and y coordinates UTM zone 14, orthometric height (z) in meters, return number, and feature classification.

LIDAR Data Manipulation

Determining above ground height of each LIDAR point was essential to development of a habitat map. Since the z values of the LIDAR points were in orthometric height, a DTM was required to obtain height above ground. The DTM was created by interpolating points that TerraScan had pre-classified as ground returns into a 1-meter raster grid. Each TerraScan file was processed separately and merged with a 100-meter buffer to minimize edge effects. A Triangulated Irregular Network (TIN) based on the Deluany method of triangulation was created from the ground points. The TIN was then converted to a raster grid providing a smoother surface by eliminating non-data areas. From this DTM, each point's height (h) was calculated by subtracting its z (z_t) from an interpolated z (z_i) value from the ground model:

$$h = z_t - z_i$$

To minimize processing time, only vegetation points within potential black-capped vireo habitat were interpolated. To separate these points, the DTM was subtracted from a raster grid of the first return LIDAR surface. All cells whose value was > 0.5 m were selected as potential habitat. To include only vegetated areas, a texture filter based on the variety of height values within a moving window was employed. Such methods have been shown to provide reliable results since they eliminate buildings and other man-made objects (Maas 1999). The resulting raster was then vectorized and each polygon given a unique identification number. The LIDAR points that fell within these polygons were assigned the polygon's unique identification number and h was calculated for these points. LIDAR data were filtered to generate 8 height classes: (1) <0 m, (2) 0-0.5 m, (3) 0.5-1.0 m, (4) 1.0-1.5 m, (5) 1.5-2.0, (6) 2.0-2.5 m, (7) 2.5-3.0, and (8) >3.0 m. After classification, an estimate of percent occupied by each height class within each polygon was calculated. An index of circularity was also estimated to identify potential donut habitat. Circularity was calculated as the square root of the patch area divided by the area of a circle with the same perimeter as the patch, with 1.0 being a perfect circle.

Polygon Selection and Field Data Verification

To assess LIDAR's ability to distinguish habitat types, polygons were assigned a specific habitat type based on the following criteria:

a) Donut habitat

1. The total area for polygons representing potential donut habitat ranged from 51 to 200 m^2. This area was selected assuming that most birds have been observed in areas with radius between 4-8 m from the central tree forming the donut.
2. Since a circular shape characterizes donut habitat, a measurement of potential donut habitat is circularity. Therefore, polygons with circularity > 0.65 were selected as potential donut habitat.
3. The presence of vegetation higher than 2.5 m was considered as an indicator of potential donut habitat. Polygons that presented 0% of the total area occupied by vegetation taller than 2.5 m were not considered for inclusion.
4. Polygons were included if at least 5% of the total area was occupied by height classes 2-5. This assumption was made to ensure the presence of understory vegetation.
5. Donuts intersecting water bodies were not included.

b) Classical habitat

1. Classical black-capped vireo habitat was assumed to present a low degree of circularity. Therefore, polygons with circularity < 0.5 were considered potential classical habitat.
2. Polygons that did not present vegetation height between 0.5 m and 2.5 m were excluded.
3. Polygons were selected if < 40% of the total area was occupied by class 8 (height > 3 m).
4. Polygons that were entirely occupied with vegetation < 1 meter were not included.

c) Linear habitat

1. Linear habitat was defined as patches with low circularity (< 0.5).
2. Polygons that did not present vegetation height between 0.5 m and 2.5 m were excluded.
3. Polygons were selected if l < 40% of the total area was occupied by class 8 (height > 3 m)
4. The presence of roads was assumed to indicate potential linear habitat. To

identify linear features within the study area, it was necessary to create a land-cover map. This map was created with a 1-m Digital Orthorectified Quarter Quad (DOQQ) acquired in February 1999. Linear features were extracted from the classified image and vectorized. A 5-m buffer was applied to these features and used to select polygons intersecting them.

Fifty polygons per habitat type (*n* = 150) were randomly selected for ground-truthing purposes. Field verification was accomplished using a customized GPS-driven field data collection application developed using ArcPad 6.0 (Environmental Information Systems Institute [ESRI]) running on Pocket Personal Computer. The field data collection application allowed us (1) to navigate to polygons that needed to be verified, (2) to view different background maps and current GPS position, and (3) to record field data using a specially designed digital format. Once each patch had been located, it was sampled at a minimum of 3 sub-sampling points. At each sub-sample location, height measurements were taken within 3 vertical vegetation strata. Stratum (1) included vegetation classes 1-4; Stratum (2) included vegetation classes 5-7; and Stratum (3) vegetation class 8. Within each stratum, vegetation heights were taken for the tallest individuals representing distinguishable vegetation strata. Dominant and sub-dominant plant species for vegetation strata were visually determined. Vegetation height was measured with either a telescoping leveling rod or a laser range finder (LaserAce® 300). Disturbances (e.g., tank trail, road), black-capped vireo presence, and habitat type were recorded as well. The ArcPad application stored all field data in ESRI shapefile format. The data were analyzed using ESRI's ArcView software.

RESULTS

Classification was most accurate for donut habitat (57%) (Table 4.1). Sources of misclassification for this habitat type were observed in polygons where lower branches of juniper "simulated" a donut structure (35%). Classical habitat was correctly classified 44% of the time (Table 4.1). Major sources of error were attributed to the presence of juniper and live oak (35%) and the presence of vegetation later identified as "mixed habitat" (21%) (Table 4.1). Mixed habitat presented a classical habitat structure, but the height of the patch was not homogeneous. Linear habitat was correctly classified only 8% of the time (Table 4.1). Two main sources of classification error were detected. The first one included the presence of juniper near linear features (i.e., roads) where lower juniper branches were perceived by LIDAR as linear habitat (44%). Mixed habitat (38%) located at the edge of linear features produced the second source of error.

Analysis of dominant species for all polygons regardless of habitat type is summarized in Table 4.2. Results indicated that the first stratum was dominated by elbow-bush (*Forestiera pubescens*) (19.73%) and shin oak (19.51%). Dominant species for the second stratum were shin oak (14.41%), Ashe juniper (8.65%), and flame-leaf sumac (7.76%). The third stratum was dominated by Plateau live oak (*Q. fusiformis*) (17.52%), Ashe juniper (13.08%), and Texas red oak (*Q. buckleyi*) (9.53%). Polygons classified as non-habitat were included in Table 4.2 to indicate their overall contribution in the sample.

The dominant species for donut habitat in the first stratum was elbow-bush (53.75%). Cedar elm (*Ulmus crassifolia*) (17.5%) and elbow-bush (14%) were the dominant species in the second stratum (Table 4.3). Plateau live oak (46.25%), and cedar elm (18.75%) dominated the third stratum. The first stratum of the classical habitat was dominated by shin oak (15.31%) and flame-leaf sumac (10.20%) (Table 4. 3). The second and third strata were dominated by shin oak (32.65% and 9.18% respectively) (Table 4. 3). The first two strata in the linear habitat were dominated by shin oak (80% and 26.67% respectively), whereas the third stratum by Ashe juniper (31.03%) (Table 4. 3).

The mixed habitat was dominated in the first stratum by shin oak (31.03%) and elbow-bush (29.31%). Shin oak (25.86%) dominated the second stratum and the third stratum was dominated by Texas red oak (24.14%) and cedar elm (20.69%). Polygons classified as non-habitat were dominated in the first stratum by elbow-bush (7.24%) and Ashe juniper (6.58%). The second stratum was dominated by Ashe juniper (18.42%) and flame-leaf sumac (10.53%). Ashe juniper (26.32%) and Plateau live oak (18.42%) dominated the third stratum.

DISCUSSION

Preliminary results indicated that LIDAR is a promising remote sensing data source for describing the vertical distribution of vegetation in areas of potential habitat for the endangered black-capped vireo on Fort Hood. The criteria from pre-defined habitat for the species produced a fairly accurate description for the donut and classical habitats. Unfortunately, linear habitat was not identified with the same degree of accuracy.

Two main sources of error decreased the model's overall accuracy. The first error source was directly related to the vertical structure of Ashe juniper. It is possible that the presence of juniper in polygons classified as either classical (where juniper presented a homogeneous height) or linear (where lower branches simulated linear structure, especially in areas near roads or gaps) reduced the overall accuracy of the classification. Homogeneous heights and proximity to roads were "correctly perceived" as described by the criteria for polygon selection. However, juniper does not provide habitat for black-capped vireo. In order to reduce this type of error, multispectral imagery will be used to remove areas dominated by juniper. We are in the process of acquiring QuickBird imagery from DigitalGlobe for the study area.

The second source of error was the presence of mixed vegetation not included as a pre-defined habitat. This mixed habitat was mistakenly classified as either classical or linear habitats. Mixed habitat closely resembled classical habitat and was composed mostly of shrubland vegetation mixed with trees (deciduous and/or evergreen). We consider that overall accuracy will improve if the mixed habitat is included into the classification scheme. The following criteria will define mixed habitat:

Mixed habitat

1. Polygons presenting circularity < 0.5 will be considered as indicator of potential mixed habitat.
2. Polygons with vegetation heights between 1 m and 2.5 m will be considered for inclusion.
3. Patches presenting between 40 - 60% of vegetation taller than 3 m will be classified as mixed habitat.

In addition to the description of potential habitat using pre-defined habitat types, we are currently exploring the use of black-capped vireo data collected during the 2002 field season to describe habitat occupied by the species. Bird data include UTM locations and habitat types where birds were observed. The UTM coordinates were used to create a point coverage depicting bird locations. The point coverage was plotted on a DOQQ and bird locations assigned to distinguishable vegetation patches. On a few occasions, probably due to GPS error, UTM coordinates for bird locations fell on roads or outside distinguishable vegetation patches. In these instances, the bird was assigned to the closest vegetation patch. After the bird locations were assigned to vegetation patches, the patches were digitized in ArcView using the DOQQ and the bird location as reference. The resulting coverage represented occupied vegetation patches. The coverage was then used to clip out above-ground LIDAR points. A point classification was generated creating point tiles derived from mean vegetation height. Clouds of points were then classified based on the mean and ± 2 SD. In this approach height classes were not pre-defined by the user but derived by points classified according to their standard deviations. Comparisons of vegetation heights taken by LIDAR and those taken in the field will be used to test LIDAR's ability to describe not only vegetation structure, but also vegetation heights.

CONCLUSIONS

Our first attempt to describe vegetation structure and potential habitat for black-capped vireo produced accuracies ranging from 8% for linear habitat to 57% for donut habitat. The removal of juniper using multispectral imagery and inclusion of mixed habitat are necessary to refine the polygon selection criteria.

Currently, data generated using bird locations is being analyzed. It is expected that a 3-dimensional vegetation classification will be produced with this approach. It is also expected that we will be able to determine potential thresholds for vegetation height preferred by the species. We assume that refinement of our selection criteria and removal of potential error sources will increase the overall model accuracy. In general we conclude that LIDAR offers an alternative to describe vegetation structure and habitat for black-capped vireo on Fort Hood.

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