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FINAL REPORT

Production of canopy grid and polygon data from LiDAR for analysis of Delmarva Fox Squirrel habitat in Dorchester County, MD

Prepared by:

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Chesapeake Bay Field Office
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Introduction

James W. Sewall Company performed analyses of Maryland DNR LiDAR data under contract to the US Fish and Wildlife Service, Chesapeake Bay Field Office, to assist in identification of Delmarva Fox Squirrel (*Scirus niger cinereus*) habitat in Dorchester County, Maryland. The Delmarva fox squirrel (DFS) is an endangered species previously found in mature forests of mixed pines and hardwoods throughout the Delmarva Peninsula (USFWS 1993). The DFS prefers tall, mature stands of pine/hardwood forest with a closed canopy and a somewhat open understory (Dueser 1988, Dueser 2000, Morris 2006). The most important variables in defining their habitat is the presence of large mature trees as these provide the greatest abundance of food and den sites for this species. Existing imagery and remote sensing data sets primarily enabled distinction of forest stands by species composition, but did not enable distinctions of stands by forest maturity. The goal of this analysis was the production of a grid of canopy heights and canopy closure (ESRI grid format), and a transformation of the grid data to polygons (shape file format) indicating forests of different height and canopy closure classes, and interpretive polygons of potential DFS habitat. The primary source of information about the forest canopy was scanning LiDAR for Dorchester County from a Maryland-wide data set acquired by the Maryland DNR in 2003. The U. S. Fish and Wildlife (USFWS) principal investigator for the study is Cherry Keller, Senior Wildlife Biologist, Threatened and Endangered Species Program, who supplied the requirements and reviewed results of pilot work to refine the process. Collaborating investigators in the development of this project include Ross Nelson, Goddard Space Center, NASA, Leslie Gerlich, GIS specialist, USFWS, and Jeff Horan, Maryland Department of Natural Resources, Forest Service. The work was performed at Sewall by Dan Boss, Senior Resource Consultant in the Forestry Department.

Summary of Process

The process for producing the final deliverables consisted of the following major steps. A more detailed description of each step is provided in the following sections of the report.

1. **Receive and prepare data**. First-return LiDAR data were provided on a mobile hard drive in ASCII (x,y,z coordinate) format, in 1200 x 1800-meter tiles covering the County. Data for bare earth elevations were also provided in the tile structure, pre-processed as the mean bare earth elevation in 2-meter grid cells. Other data included NWI wetlands and land use polygon data sets.
2. **Transform point data to grid data.** LiDAR point data were grouped into 6-meter square grids resulting in a 200 x 300 cell grid for each tile. For each grid cell, four different canopy height measures, as well as percent canopy closure (cc) were computed from the LiDAR points falling in that cell.
3. **Combine the measures within each tile, and then merge the grid tiles into larger groups.** Grids with all five measures in each of two data types (integer and reclassified) were created for each tile. The tiles were then combined into 25 grids covering the County, using groups of about 40-50 tiles each.
4. **Transform grid cells to polygons.** The primary product of the analysis, and the primary analytical challenge, was the production of meaningful DFS habitat polygons. This involved developing a classification of habitat in terms of height and canopy closure, generalizing from the gridded data to useful polygons, and incorporating wetlands and land use polygon data to add information not provided by LiDAR for discriminating various classes of non-forested land.
5. **Combine all groups to create county-wide data sets.** After polygons were generated for all groups, the final step was to combine the 25 groups of data into a single county-wide data set. In addition to the countywide polygon data set, two county-wide grids were created (one having integer values for height and cc and the other with the values reclassified into 9 height groups and 5 cc groups).

Most of the processing was done in the Arc Workstation (v 9.1) environment, supplemented by SAS for initial processing of the LiDAR data. Review was done primarily in ArcGIS (v. 9.1). The data set and other files referred to are listed relative to the root directory ("M:") on the primary delivery medium, a 250-gigabyte mobile hard drive (MHD) provided for the study by USFW. Procedures were encoded as ArcInfo macros (aml's), which are included with the delivery in folder M:\JWS\process\aml.
Each of the above steps will be reviewed in more detail below.

Step 1. Receive and prepare data

The LiDAR data for this analysis originated in a project conducted for the Maryland DNR in 2003 and 2004. First return LiDAR data points were obtained from DNR by USFWS and provided to Sewall on MHD. The first returns for Dorchester County were flown in the spring of 2003 (April 16 – June 11) and were provided in 1,026 tiles, each 1200 meters x 1800 meters. The tiles are indexed in the shapefile smallgrid.shp (M:\JWS\process\arc\smallgrid.shp).

Also provided in this tile structure were bare earth elevation points for the center of each 2-meter x 2-meter grid cell. These had been pre-processed for MD DNR by the LiDAR contractor. Quality control showed that vertical data had an RMSE value of 14.3 cm at the 95% confidence level (see M:\LiDAR2004GriddedDEM.htm).

Other data critical to the analysis included National Wetland Inventory (NWI) polygons for the County (provided by USFW in a county-wide data set), the Maryland landuse\landcover data for Dorchester County (dorclu02.zip downloaded from http://www.mdp.state.md.us/zip_downloads_accept.htm), and 2005 National Agricultural Imagery (NAIP) true color orthophotography downloaded by Sewall through the USDA data gateway (http://datagateway.nrcs.usda.gov/).

The NWI data were re-processed to create an ArcInfo polygon coverage with three polygon classes – (1) open water, (2) emergent wetland, and (3) upland. An excel spreadsheet (M:\JWS\process\doc\wetland_list.xls) is included on the MHD showing how each of the detailed wetland classes was re-coded to the general class. The resulting, dissolved, water/wetlands/upland coverage is M:\JWS\process\arc1\dorwetlddsd1.

An ArcInfo polygon coverage indicating the general location of forested land was created by extracting forested polygons from the Dorchester land use coverage. The horizontal accuracy of the polygon boundaries in this data set was less than the other data sets due to its origin in LANDSAT (see M:\JWS\process\base\landuse_landcover\Metadata\metalu02.htm). The resulting forest polygon coverage is M:\JWS\process\arc1\dorcforest.

The 2005 NAIP imagery was used as a backdrop during processing and review of the classifications because this provided the most recent imagery of the area.

Step 2. Transform Point Data to Grid Data. Extract heights from LiDAR data and prepare gridded height and canopy closure data for each data tile.

In this step, we transformed the original LiDAR x,y,z points to a mean height and mean canopy closure value for a 6-meter grid. We chose a 6 meter grid size for two reasons. First, the 6 meter grid is large enough to include a reasonable sample of points (numbers varied considerably but averaged about 23 points/6-meter grid) to calculate heights and crown closure, and it provided nine 2-meter cells that contained ground elevation data. Second, we wanted the grid size to be an even devisor of a 30 m Landsat Thematic Mapper pixel. Three TM-based land cover data sets are available for Dorchester County and surrounding areas, and we wished to mitigate the need to resample the gridded data should the need arise to

co-register the laser grids with TM products. The three TM land cover maps include(1) the Maryland Department of Planning/Land Use Land Cover (1992, 1993); (2) The 2001 National Land Cover Dataset available from the USGS; and (3) the 1995 GAP land cover map.

The LiDAR data points are x,y,z data points where z is the *elevation* of the first return or canopy (x and y provide location on the earth). To compute actual canopy height from the ground, we subtracted the ground elevation described for the 2-meter grid from the z value of every point that fell in that 2-meter grid. We then calculated the four measures of canopy height and a measure of canopy closure for all the points in the 6-meter grid area. These values were then transformed to integers (rounded up so there were no decimals) to enable grid processing.

2m	2m	2m
2m	2m	2m
2m	2m	2m

5 Values – (four measures of average height and one canopy closure value)

We chose to calculate four measures of height because past research using LiDAR had found that different means were more or less appropriate for different estimates. For example, initial work in Delaware (Nelson et al. 2003; 2005) utilized average canopy height (hta), i.e., the average height of all pulses along a linear laser profile, to identify "tall" stands where Delmarva fox squirrels might be found. This Delaware data was taken with leaf-on in the summer of 2000. The quadratic mean height (qmhc) tends to weight taller trees more heavily, and this variable often proves useful for predicting forest biophysical characteristics, e.g., merchantable volume and total aboveground biomass. The quadratic mean may also provide better estimates of canopy height when LiDAR data are flown at leaf off. The Dorchester County data flights occurred from April 16 to June 11 2003, and about half the flights were likely flown with leaf off. Other estimates of height may be better for estimating forestry values of interest (Nelson et.al 2003).

Specific Processing Steps: Specific processing for this step was driven tile-by-tile by executing grid_heights.aml with parameters appropriate to the tile. This macro set up the appropriate data and called a SAS routine. The SAS routine grouped the point data of the LiDAR first-returns and produced the five required mean values (see below) for each 6-m square grid cell. The output of the SAS routine was then used by ArcInfo to build a floating point grid for the tile on each of the five height/canopy closure measures. Data were then processed for each tile and each measure to create a combined integer grid (height measures ranged from 0 to 35 meters and canopy closure ranged from 0 to 100 %) and a combined reclassified grid (9 classes for height measures and 5 classes for percent canopy closure).

The essential basic data for computing heights are derived from the difference between first return values and the bare earth values within each cell. The requested height parameters were: 1) qmha - quadratic mean height for all pulses; 2) qmhc - quadratic mean height for canopy pulses, where canopy is defined as including all raw measures greater than 3 meters; 3) hta – average height, all pulses; and 4) htc – average height, canopy pulses. Canopy closure was computed as the percent of pulses within the cell exceeding 3 meters. Formulas for computing the five different parameters for each cell from a number of first returns were provided by Ross Nelson (Ross.F.Nelson@nasa.gov). Their calculation is described as follows (quoted from Ross Nelson e-mail):

- quadratic mean height, all pulses (qmha), is calculated as the square root of the average of the sum of squared heights. So, for instance, if you have 4 first returns in a given grid cell, and the 4 tree heights (range to ground minus range to first target) are as follows: 10m, 12m, 2m, 8m, then the quadratic mean height, all pulses (qmha) would be:
  qmha = square root [(10**2 + 12**2 + 2**2 + 8**2)/4] = 8.83 m
- quadratic mean height, canopy hits only (qmhc), where a canopy hit is defined as any height >=3m, is:
  qmhc = square root[(10**2 + 12**2 + 8**2)/3] = 10.13 m
- average height, all pulses (hta) would be:
  hta = (10+12+2+8)/4 = 8m

- average height, canopy hits only (htc) would be:
  htc = (10+12+8)/3 = 10m.
- canopy closure (cc) for this grid cell would be the number of first return heights >=3m divided by the total number of pulses in the grid cell, or
  cc = (3/4)*100 = 75%.

Quadratic measures tend to place more emphasis on the taller trees.

Because the data for bare earth were provided in 2-meter grid cells, the heights and squared heights were computed first on 2-meter cells (subtracting the 2-meter bare earth value from each first return in each 2-meter cell). The five means were then computed for the 6-m cell. Following all computations for a tile, ArcInfo commands were used to create a floating point grid for each of the parameters.

Transform specific heights to height and canopy classes. In the last processing of this step, the floating point grids were processed to create a set of integer grids and a set of reclassified grids. The reclassification grouped the individual measures into height and canopy classes. In addition to the two output grids for canopy, this step creates a 6-meter bare earth grid that can be used for reference during data review. This is an average of the 2-meter cells.

The height classes created are as follows (class intervals in meters):

Class	>= Low	< High
1	0.00	3.00
2	3.00	6.60
3	6.60	9.70
4	9.70	12.80
5	12.80	16.40
6	16.40	20.00
7	20.00	25.00
8	25.00	30.00
9	30.00	50.00

The reclassification for canopy closure was as follows:

Class	>= Low	< High
1	0.00	0.10
2	0.10	0.30
3	0.30	0.60
4	0.60	0.80
5	0.80	1.00

These height classes were based on information obtained from Delaware LiDAR profile data paired with on the ground vegetation surveys (Nelson et al. 2003, 2005). This data set suggested that DFS habitat identified by ground surveys, was more often found in forests where LiDAR data indicated the trees were greater than 20 m tall and had 80% canopy closure. To enable collaboration with foresters, these data were also analyzed to estimate the LiDAR height cutoffs that best distinguished between the forest classes of **sawtimber, poletimber** and **sapling** forest stands. In the Delaware LiDAR data set these height cutoffs separating these three stands types were 12.8 m and 6.6 m. These forest classes are typically defined by the dbh size of the trees and further evaluation is need to determine if the LiDAR data will ultimately enable distinctions of these forest classes as well. However, the height classes chosen were intended to make the data more relevant to foresters and to reflect DFS habitat.

Step 3. Combine the measures within each tile, and then merge the grid tiles into larger groups.

In this step, five input grids for each tile in a group are converted to group grids, each with all five measures. This is done for each of the two data types (integer and reclassified) that were created for each tile in step 2. The grid grouping scheme is contained in M:\JWS\process\shapes\ batch_group_setup.shp. The figure below shows how the grids were grouped. Tiles determined to be all water are indicated in a light blue crosshatch. These tiles were not processed. The macro that performs the grouping is M:\JWS\process\aml\combine_grids_by_group.aml.

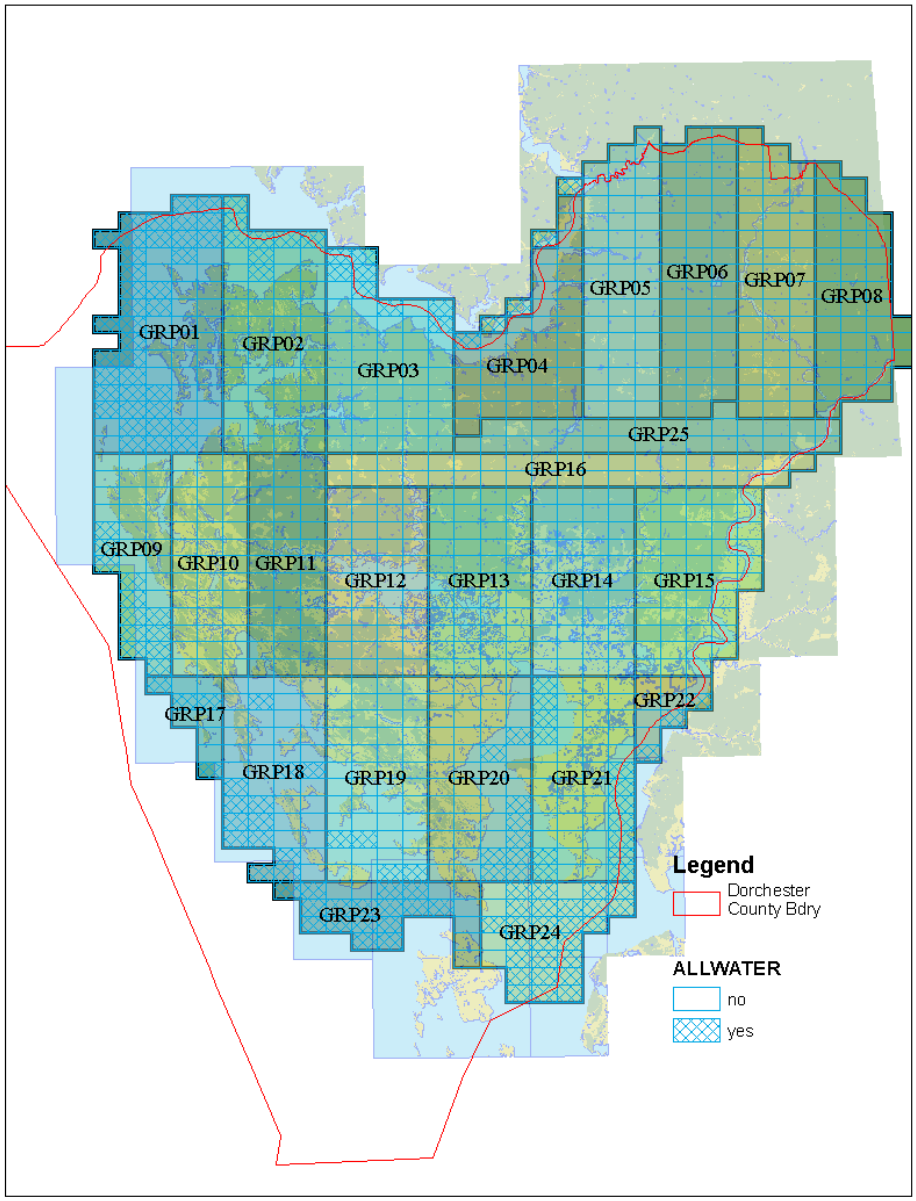

Figure 1: Tile groups used in processing

Step 4. Transform Grid Data to Polygons.

This step combined grid cells into polygons based on habitat classes that reflected combinations of canopy cover and canopy height and a developed model as to suitable habitat for Delmarva fox squirrels. Several tasks were involved in this step, but Figure 3 provides an illustration of several phases of this process. The process, driven by M:\JWS\process\aml\make_polygons.aml (this controls the process and executes several other aml's), was conducted group by group on the reclassified grids and involved the following tasks:

- Define nine habitat classes based on canopy height and canopy closure and reclassify the 6-meter grids using these habitat classes. (Input was reclassified height and cc grids "GRPnnCOMBRC", where the three habitat classes considered potentially suitable for DFS are 1, 3, and 5 (see below);
- Using this habitat class grid, create polygons based on the habitat classes;
- Use land use and wetlands/water coverages to separate the shortest height class into agriculture, wetlands, and shortest forest (recent clearcuts or young forest);
- Execute "cleanup_small_clusters.aml" to group small clusters within their habitat type;
- Using the proposed model for identifying potential Delmarva fox squirrel habitat, identify area of potential habitat meeting the specified criterion. These were habitat classes 1 and 3 (the tallest forest) and habclass 5 if there was at least 20% of the area in habclass 1 and 3;
- Perform cleanup to eliminate small polygons.

Task 1 - Develop Habitat Classification Scheme (nine classes used). The assignment of habitat suitability classes was based on the scheme diagrammed in Figure 2. County-wide acres for the final polygon classes are shown within each cell as well as the general habitat suitability class that was assigned. This habitat classification scheme was developed to help identify Delmarva fox squirrel habitat (mature forest with a closed canopy) and to provide foresters with information on regenerating stands of forest. Development of the habitat classification scheme is based on the following.

Delmarva fox squirrel habitat is mature forest with a mix of hardwoods and pines. The larger mature trees produce larger quantities of food (both hard and soft mast) and provide potential den sites. Several studies have identified variables that can be useful in identifying DFS habitat. Dueser et al. (1988) determined that forest stands with a higher proportion of trees with 12 inch or greater dbh, higher canopy closure, and a more open understory were more likely to support DFS. Morris (2006) also determined that the presence of taller trees and a closed canopy were significant predictors of points within a forest where Delmarva fox squirrels were detected. In addition, LiDAR transects conducted in Delaware found that 40-meter transects where canopy height (qmhc) was greater than 20m tall and canopy cover was 80% or greater were more likely than not (78%) to also be considered DFS habitat using the Dueser habitat model (Dueser 2000). Thus we developed a LiDAR model for the polygons that was informed by this previous work, and the relationships identified. Habclass 1 (greater than 20 m tall and greater than 80% canopy) reflects the LiDAR transect data from Nelson et al. (2005). We included habclass 3 (next tallest trees), and habclass 5 only if the polygon contained at least 20% of the area in hablcass 1 and 3 (tallest trees). We included these because polygons of mature forest tend to be larger mixes of uneven tree heights and DFS will use stands with some younger trees if there is sufficient abundance of large trees as well. This LiDAR "model" of DFS habitat suitability is not a proven or tested model for predicting DFS occurrence, however, it is informed by previous work and is,at the very least, a description of mature forest. This model can be compared to known DFS stands in the future to further evaluate its usefulness. The height classes of young, regenerating stands of forests are intended to provide data useful to foresters.

Figure 2: Polygon Generalization Codes Followed by Habitat Eligibility (Y = Eligible, N = Not Eligible) Based on Height, Canopy Closure from LiDAR, Modified by Wetlands and Land Use

<table>
<tr><th></th><th colspan="5">Canopy Closure</th></tr>
<tr><th>QMHC (Height)</th><th>5 (80-100%)</th><th>4 (60-80%)</th><th>3 (30-60%)</th><th>2 (10-30%)</th><th>1 (0-10%)</th></tr>
<tr><td>9 (>= 30 m)</td><td rowspan="3">1 - Y
17679 a.</td><td rowspan="2">2 - N
0.5 a</td><td rowspan="2">4 - N
0.2 a</td><td colspan="2" rowspan="5">6 - N
171 a.</td></tr>
<tr><td>8 (25-29.99 m)</td></tr>
<tr><td>7 (20-24.99 m)</td><td colspan="2" rowspan="2">3 - Y
26849 a.</td></tr>
<tr><td>6 (16.4-19.99 m)</td></tr>
<tr><td>5 (12.8 -16.39 m)</td><td colspan="3">5 - Y (if with > 20% 1,3) - 27614 a.</td></tr>
<tr><td>4 (9.7-12.79 m)</td><td colspan="5" rowspan="2">7 - N
43518 a.</td></tr>
<tr><td>3 (6.6 - 9.69 m)</td></tr>
<tr><td>2 (3.0 - 6.99 m)</td><td colspan="5">8 - N
77816 a.</td></tr>
<tr><td>1 (0 - 2.99 m)</td><td colspan="5">9, 10, or 11 - N* - 211078 a.</td></tr>
</table>

* 9 - recently clearcut; 10 - emergent wetland; 11 - other non-forest (agricultural, developed, etc). Open water is null.

Classes 1 and 3 are considered suitable DFS habitat. Class 5 is also considered habitat if there is a sufficient proportion of the taller classes (1 and 3). In order for class 5 to participate as DFS habitat it must occur in conjunction with classes 1 and 3. The cutoff proportion of area used was 20% (required minimum % 1 and 3 associated with a 1, 3, 5 grouping).

Task 2 – Using the habitat classification scheme, move from grid to polygons. Following assignment of each grid to a habitat class, a habitat class grid was created. A filter was run on the initial grid to replace cells in the grid based upon the majority of their contiguous neighboring cells (ArcInfo GRID command MAJORITYFILTER (arguments 8, HALF)). The region used for this filter was restricted to the 8 surrounding cells. Following this, polygons were generated by habitat class.

The initial polygons created were very detailed, with polygon boundaries surrounding each unique grouping of habitat class codes. The first cleanup step eliminated all non-habitat, non-edge polygons that corresponded to one grid cell (parameter *non_hab_elim* = 36 (sq meters)).

Task 3 – Use land use data to separate shortest height class by covertype. The next step incorporated the information from the land use coverage identifying forested areas and the wetlands data identifying emergent wetlands (assigned class 10) and open water and separating them from open (non-forested) land (assigned class 11). The macro executed for this process was id_forest.aml.
The macro finished by defining a generalized habitat class attribute, with polys with habitat classes 1,3, and 5 being classed as habitat (gen_hab = "Y") and all others classed as non-habitat.

Task 4 – Clean up small clusters. Another cleanup step followed. This involved 4 passes of a macro (cleanup_small_clusters.aml) that combined small polygons with larger neighbors of the same general habitat class (using attribute GEN_HAB to determine the general habitat class). Four passes of this routine were needed to converge to a point where the most polygons meeting the criterion that was chosen had been eliminated (parameter *small_cluster* = 972 – approximately .1 hectare).

Task 5 – Identify areas of potential habitat that can be considered suitable only if it is proximate to taller habitat classes. The next step was to determine which predominantly habitat class 5 polygons were eligible to be considered DFS habitat and which were not. The criterion arrived at, couched in terms of the habitat classes developed in the study, was that classes 1 and 3 needed to represent at least 20% of a polygon's area in order for the polygon to qualify as habitat. The macro that performed this analysis was remove_ineligible_habitat.aml. The key parameter for this was *prp_1_3*, which was set to 0.2. Statistics were generated for each general habitat polygon (GEN_HAB = "Y") showing the total proportion of habitat classes 1 and 3 in the polygon. If this number was less than 0.2, the polygon's GEN_HAB value was changed to "N".

An issue with early pilot runs was a difficulty that arose because of the relative inaccuracy of the landuse polygons compared with the LiDAR data sets. Due to this inaccuracy, large open areas along the edges of fields were being classed as cleared forest and assigned the "recent clearcut" value of 9 due to overlap with "forest" polygons from the land use coverage. Early attempts to correct this problem by simply using a minimum acreage criterion were inadequate, resulting in many areas still being misclassified. The macro that was created and used to correct this problem was set_clearcut_by_fnf_proportion.aml. The need was to determine if polygons identified as recent clearcut were really forest that had been cleared, or a sliver polygon that was more likely to be of agricultural or other cleared land use. The rule-of-thumb used was that if more than 70% of the boundary was with forest, the polygon was considered to be cleared area under forest land use. Otherwise, it was considered other-cleared-land use. 70% criterion was a cutoff value that seemed to make the distinction between agriculture and forest land use fairly consistently. The aml computed the proportion of the boundary that was between forest and non-forest (fnfprop), and tested that value against 0.7 to determine which way to assign it.

Task 6 – Perform cleanup to eliminate small polygons. Following the elimination of small non-habitat holes (the criterion used for this was 144 square meters (4 grid cells)), polygon boundaries were generalized to remove some of the stair-stepping (using the ArcInfo generalize command, with a weed tolerance of 11 on the bendsimplify option). The resulting polygon coverage was then dissolved to create two final polygon coverages – one for the detailed habitat classes (GRPxxHCDTL) and one for the general habitat classes (GRPxxHCGEN). See Figure 3 for illustration of final product.

Step 5. Combine all groups to create county-wide data sets

After completion of grid processing and polygon creation for all groups, group data sets were merged to create county-wide deliverable data sets. The processes for this were driven by macros combine_all_grid_groups.aml for the grids, and combine_all_poly_groups.aml for the polygons. The resulting grid data sets were combintall (the combined integer grid) and combrcall (the combined reclassified grid. A water mask was used to eliminate open water from these grids. Due to limitations of the ArcInfo GRID processor, the combined integer grid contained a reduced set of attributes (qmhc, qmha, htc, hta, and rccc – the 5-class reclassified canopy closure). However, the combined reclassified grid included all reclassified heights and canopy closure (RCQMHC, RCQMHA, RCHTC, RCHTA, RCCC), the habitat class assignment before (HABCLSINI) and after (HABCLSPLY) polygonization, and the general habitat class (GENHABCLS). This table was used to do the crosstabulation shown in Table 1 of the final habitat classes (per the polygons) with the grid height and crown closure values. Table 1 therefore reflects the grouping that occurred during the generalization process.

Table 1: Acres by final polygon HABCLASS, RCQMHC and RCCC

Sum of ACRES		RCQMHC									
HABCLSPLY	RCCC	9	8	7	6	5	4	3	2	1	Grand Total
1	5	57	1,362	9,783	3,577	1,164	157	27	4		16,130
	4	0	18	279	309	244	56	17	5		928
	3	0	4	75	136	166	45	19	9		453
	2	0	1	16	25	33	20	10	10		114
	1	0	0	4	5	7	5	3	6	25	56
1 Total		58	1,385	10,156	4,051	1,614	282	76	33	25	17,681
2	5		0								0
	4		0	0				0			0
	3		0	0							0
	2		0			0	0		0		0
	1									0	0
2 Total			0	0		0	0	0	0	0	1
3	5	0	16	3,106	14,431	4,824	500	62	7		22,946
	4		1	192	1,041	793	170	41	9		2,246
	3		0	54	291	429	128	44	18		964
	2		0	11	50	79	47	23	22	0	232
	1		0	3	10	15	9	6	12	45	100
3 Total		0	18	3,365	15,822	6,140	854	176	68	45	26,488
4	4		0	0							0
	3		0								0
	2			0	0						0
	1			0					0	0	0
4 Total			0	0	0				0	0	0
5	5	0	6	532	4,438	15,125	2,066	132	10		22,308
	4	0	0	52	425	1,838	428	77	14		2,835
	3		0	49	329	1,072	304	85	31		1,869
	2		0	9	55	168	103	46	39		421
	1		0	3	12	29	18	12	24	82	179
5 Total		0	7	644	5,260	18,231	2,919	351	118	82	27,613
6	5			0	0	0	1	0	0		2
	4		0	1	1	1	1	0	0		5
	3		0	1	7	7	5	2	1		23
	2		0	6	25	32	10	4	4		82
	1		0	3	9	10	3	3	6	26	59
6 Total			0	11	42	50	21	9	11	26	171
7	5		0	24	342	3,038	12,798	8,176	682		25,059
	4		0	4	45	433	2,289	2,675	649		6,095
	3	0	0	3	31	307	1,889	2,607	1,057		5,894
	2	0	0	6	39	234	833	1,482	1,080	0	3,674
	1		0	3	16	71	215	393	556	1,546	2,800
7 Total		0	1	40	472	4,082	18,025	15,332	4,024	1,546	43,522
8	5	0	0	3	20	78	181	566	1,813		2,661
	4	0	0	2	12	40	119	332	1,868		2,373
	3	0	0	3	14	46	141	391	3,548		4,144
	2	0	0	4	17	43	75	227	3,339	1	3,705
	1	0	0	2	7	13	23	68	1,462	1,576	3,149
8 Total		0	1	15	70	219	539	1,583	12,030	1,576	16,033
9	5		0	2	11	35	73	29	11		161
	4	0	1	3	10	22	55	34	17		143
	3	0	2	9	27	55	110	91	77	0	372
	2	0	1	17	58	114	133	154	269	0	747
	1	0	1	11	30	57	68	94	326	4,937	5,523
9 Total		0	6	42	137	283	439	401	700	4,938	6,947
10	5		0	1	7	45	95	52	19	0	218
	4			1	3	23	85	68	44		223
	3		0	1	5	28	126	154	188		503
	2	0	0	2	11	47	109	211	519	0	898
	1	0	0	1	6	23	56	128	539	74,995	75,749
10 Total		0	0	5	33	165	471	613	1,309	74,995	77,590
11	5	0	0	6	49	235	531	317	207	0	1,344
	4	0	0	3	15	63	266	268	236		853
	3	0	1	6	26	87	358	479	675		1,632
	2	0	1	12	52	156	290	482	1,221	1	2,216
	1	1	1	8	30	92	174	276	1,096	118,594	120,271
11 Total		1	2	35	172	634	1,619	1,822	3,435	118,594	126,314
Grand Total		60	1,420	14,314	26,058	31,420	25,168	20,365	21,728	201,828	342,360

Note that because the polygon habitat class acreage values in this table originate from a 6-m grid version of the final polygon habitat class, they are close to but do not exactly match the acreages obtained by summarizing acreage by habitat class in the polygon data set (Table 2). The acres shown here include the detail of small isolated 6-m grids of different height classes that were subsequently filtered and gouped into a larger polygon of one habitat class. The polygon coverages grp_allhcdtl (the detailed habitat classes) and grp_allhcgen (the general habitat classes) were converted to shapefiles and the water and other hab_class null polygons deleted. The final shapefiles were grp_allhcdtl polygon.shp and grp_allhcgen polygon.shp.

Land in Dorchester County
Table 2: Summary of Polygon Acreages by DFS Habitat Class

HAB_CLASS	Acres	Percent
1	17,679	5.2%
2	1	0.0%
3	26,489	7.7%
4	0	0.0%
5	27,614	8.1%
6	171	0.0%
7	43,519	12.7%
8	16,032	4.7%
9	6,945	2.0%
10	77,816	22.7%
11	126,318	36.9%
Total	342,584	100.0%

Note that habitat class 2 and 4 and 6 (tall trees with very low canopy closure) are only found in less than one percent of the county. Habitat class 6 may reflect areas where salt-water intrusion is causing some die-offs in forest near the water, but this interpretation needs to be further investigated. Habitat Class 10 was interpreted as wetlands, and 11 is agriculture or other cleared lands. Also, there were 22,377 acres of Habitat Class 5 that was considered suitable for DFS and 5236 acres that were not considered suitable. Thus there was 66,546 acres of habitat considered suitable for DFS using this model, and 71,732 acres of forest considered unsuitable for DFS. Further evaluation of this model for DFS is needed.

The maps in Figure 3 depict the transformation from grid data to polygon data for a small area of the County.

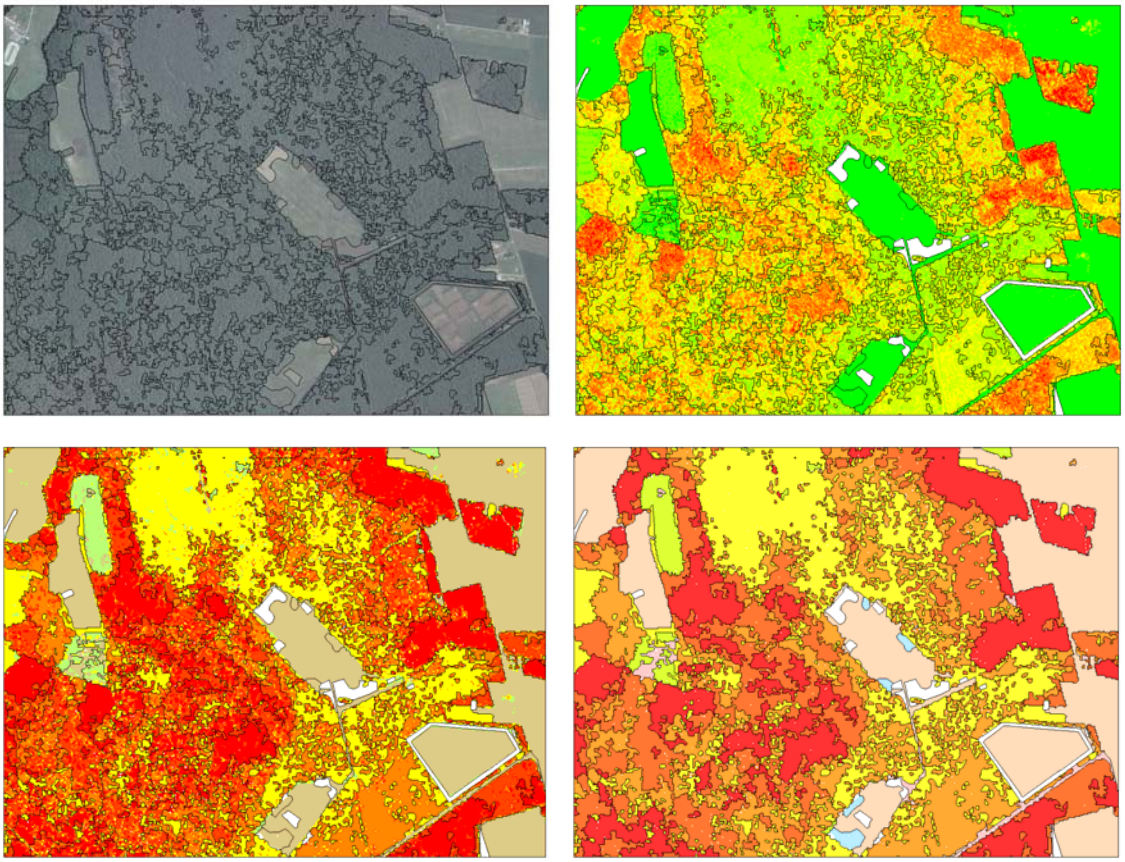

Figure 3: Sequence showing effects of generalization. All frames show the final polygon layer superimposed for reference (fine black outlines). Images shown are: Top: NAIP color photography, QMHC grid (red is tallest). Bottom: habitat classes before (left) and after (right) polygonization and generalization. Red represents the most suitable habitat. The tan color in the left represents all non-forest; in the right this is broken down further to show wetlands (light blue), agriculture or other cleared land (tan), and pink (recent clearcut – see middle left of lower right frame).

Summary

Based on the feedback from USFW's field checking of the polygons, there is a useful predictive relationship between the habitat classification developed in the analysis and the kind of forest that is considered to be good DFS habitat. The LiDAR data were consistent and appear to have been appropriate to the task. The collaborative relationship between USFW and Sewall was productive in defining and implementing the final process and the refinements to develop a useful classification.

References

Dueser, R.D., J.L. Dooley, Jr. and G.J. Taylor. 1988. Habitat structure, forest composition and landscape dimensions as components of habitat suitability for the Delmarva fox squirrel. Pp. 414-421 in R.C.

Szaro, K.E. Severson, and D.R. Patton (eds.), Management of amphibians, reptiles and small mammals in North America. U.S. Forest Service Technical Report RM-166.

Dueser, R.D. 2000. A review and synthesis of habitat suitability modeling for the Delmarva fox squirrel (*Sciurus niger cinereus*), with a proposal for future conservation planning. Report to Delaware Bay Estuary Project, USFWS, Contract number: 51120-7-0085a. 66 pp.

Morris, C. M. 2006. Building a predictive model of Delmarva fox squirrel (Sciurus niger cinereus) occurrence using infrared photomonitors. MS Thesis, Virginia Polytechnic Institute and State University. 132 pp.

Nelson, R., C.Keller, M. Ratnaswamy. 2005 Locating and estimating the extent of Delmarva fox squirrel habitat using an airborne LiDAR profiler. Remote Sensing of Environment 96:292-301.

Nelson, R., M. A. Valenti, A. Short, and C. Keller. 2003. A multiple resource inventory of Delaware using airborne laser data. BioScience 53:981-992.

Note on aml's included with the delivery:

All aml's used in the process are included on the mobile hard drive in the folder M:\JWS\process\aml. The folder M:\JWS\process\aml\batch_amls contains batch aml's. These were used to drive the process through the various tiles. All aml's are set up to run with the folder structure provided on the MHD, with the amlpath set to M:\JWS\process\aml, M:\JWS\process\aml\batch_amls. The two primary macro's are grid_heights.aml, which drives the process of creating grids from the LiDAR first return and bare earth values; and make_polygons.aml, which is run by group and acts on the combined grids to create the generalized polygons for each group. In order to facilitate the re-execution of the polygon creation process, should there be a need to change some of the parameters, make_polygons.aml can be re-run with different parameters. A batch aml that will re-run all groups is provided - batch_rerun_polygon_creation.aml. However, neither this aml nor the batch commands for re-running groups, call make_polygons.aml with all parameters – re-running these as provided will currently use the default values (those mentioned in the text above) unless different values are provided as arguments. The SAS routine that is called by grid_heights.aml to process the LiDAR data to gridded heights has not been provided. The macros are not guaranteed in any way, and should only be used by USFW's Chesapeake Bay Field Office with the Dorchester County data.