

Contributions of Donald J. Lipscomb to early forestry GIS and low cost applications to address issues of southern forestry

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Abstract

This paper is a tribute to Donald J. Lipscomb who spent a career dedicated to illustrating how one might use GIS technology to improve forestry practice in the Southeastern United States, primarily through innovations using low cost technology that would be available to smaller forest landowners. His work included GIS applications to stand mapping and forest inventory, mapping red-cockaded woodpecker habitat, mapping and evaluation of streamside management zones, and evaluation of land use in and adjacent to protected lands across North America.

Keywords: forest inventory, red-cockaded woodpeckers, streamside management zones, habitat mapping, history of personal computer GIS.

1 Introduction

Don Lipscomb, a native of Culpepper Virginia, came to Clemson University after forestry training at the Lake City Ranger School and Stephen F. Austin University where he earned an MS degree in Forestry. His life experience included service with the US Air Force, where he was a technician on the old Nike air defense systems, and service with the Peace Corps. His work with the Peace Corps included engaging in tropical forestry in the mountains of Colombia, where met his wife Marina. After returning from Colombia, Don took a job

with Kirby Lumber Company in Silsbee, Texas to manage their tree improvement projects. Those varied experiences prepared Don well for the challenges of forest management on a small property.

In November 1974, Don Lipscomb became the forest manager of the 7,500-acre Hobcaw Forest in Georgetown, SC. Hobcaw Forest is part of the estate of Belle W. Baruch and, in accordance with her will, the property is owned by the Belle W. Baruch Foundation with a mandate to be used for research by colleges and universities of South Carolina. In early 1975, Clemson contracted with the Foundation for forest management on the property. Don always had a dual mandate to develop the forest to produce forest and wildlife research opportunities, while also producing enough revenue to pay for management activities. He understood the importance of integrating spatial relationships into forest management planning, and worked to develop GIS solutions that could be supported by this relatively small forest ownership.

During his work on the Hobcaw Forest, Don focused on forest inventory and mapping and impacts of forest management on the dense population of the endangered red-cockaded woodpecker (*Picoides borealis*) found on the forest. Forest inventory and mapping began as processing field data to data entry sheets, transporting those sheets to Clemson University for processing on the University computer, receiving results as printed forms, and then transferring those results to blue print copies of a forest map derived from a semi-controlled mosaic of aerial photographs (Figure 1). During Don's twenty years at the Hobcaw Forest he created a \$10,000 personal computer-based GIS system that incorporated stand inventory data, an orthophoto based stand map, and geo referenced historical and current aerial photography. Don's GIS mapping also contributed to red-cockaded woodpecker habitat management and evaluation contributed uniquely to the recovery efforts for that endangered species.

Hurricane Hugo (September 1989) had a profound effect on Don's career. It destroyed the source of his salary, as revenue from the sale of pine sawtimber from Hobcaw Forest was a large part of the income to the Baruch Foundation Trust. Following the hurricane the Baruch Foundation was forced to suspend payments to Clemson for forest management and Don relocated to Clemson and worked as a member of the staff (Research Forester). Don later said that disaster was one of the best things that could have happened to his career.

The GIS forest inventory mapping system he designed was used in forest damage assessments, revising the inventory, and mapping surviving red-cockaded woodpecker nest and roost trees. GIS analysis also provided the first GIS based examination of forest mortality due to hurricane storm surge. While at Clemson, Don also went on to contribute to mapping streamside management zones for South Carolina Best Management Practices, and during his retirement he worked on land use analysis of all protected natural areas in North America.

Development of low cost GIS solutions for southeaster forestry problems was a prominent feature of Don's career. He shared many of those solutions in the Southern Forestry GIS conferences from the first in 1996 (Lipscomb and Williams, 1996; Williams and Lipscomb, 1996) continuing until his retirement in 2008, and in a later paper in *Mathematical and Computational Forestry &*

Natural-Resource Sciences in 2010 (Lipscomb and Baldwin, 2010). This paper outlines contributions Don made to southern forestry GIS practice during his career in four areas outlined above.

2 Forest Inventory and Stand mapping

Forest inventory is one of the first requirements for professional forest management, and Don began developing one for the Hobcaw Forest soon after he arrived. In 1975, the Hobcaw Forest inventory was composed of stratified sampling for a 3% sample intensity of the entire forest. The forest was stratified into 175 uniform stands using aerial photo interpretation and surveyed by field crews with tally sheets. Field data were transcribed onto reel tapes and analyzed on the Clemson University main frame computer system. Analysis reports were printed on computer sheets and bound into a report. GIS analysis of that data, consisted of Don hand-copying data from the report onto blue-print copies of a stand map made from a mosaic of aerial photos of the property (Figure 1). Data layers were individual blue-print maps with data such as species, age, basal area, volume, etc., hand-written on the map. Overlay analysis was done literally on a light table to see spatial relationships.

By the time the ten-year periodic inventory was due in 1985, the state of computer technology had improved with the ability to access the Clemson main computers with modem connections and run analyses remotely. However, Hobcaw Forest telephone connections were not sufficiently reliable for remote computer operation, due to frequent (every 2-5 minutes) disconnections that halted execution. This problem led Don to make a sizable investment (\$8,700) for the management of a small forest, an Apple II desktop computer with an auxiliary Z80 (8 bit) processor and dual 8" floppy drives with 1 mb of total storage. This system could run the TVA Inventory Processor program developed for the Microsoft Disk Operating System (MS-DOS) (Bean and Ellis, 1984). Field data were recorded onto specially formatted data sheets that corresponded to the input format of the program; allowing data entry as a two-step process rather than the four steps of the 1975 analysis. Although the Apple II ran for over 72 hours the entire forest inventory was analyzed in less than a week.

The late 1980's was a time of rapid expansion of desktop computing capabilities, with a number of manufacturers developing machines similar to the IBM-PC, all capable of running MS-DOS. ESRI had developed a version of their ArcInfo, GIS software that could be run on machines with MS-DOS. One tremendous advantage of PC-ArcInfo was that ESRI also developed an exchange format that allowed GIS data from any ESRI platform to be used on the PC version.

Don took advantage of these developments to create a forest inventory GIS system for the Hobcaw Forest. The Apple II had hardly cooled down from the inventory analysis when Don replaced it with a Compaq Deskpro 386. Although most manufacturers' products were derogatorily called PC clones, Compaq used an Intel 80386 (32 bit) processor to make a machine superior to the IBM prod-

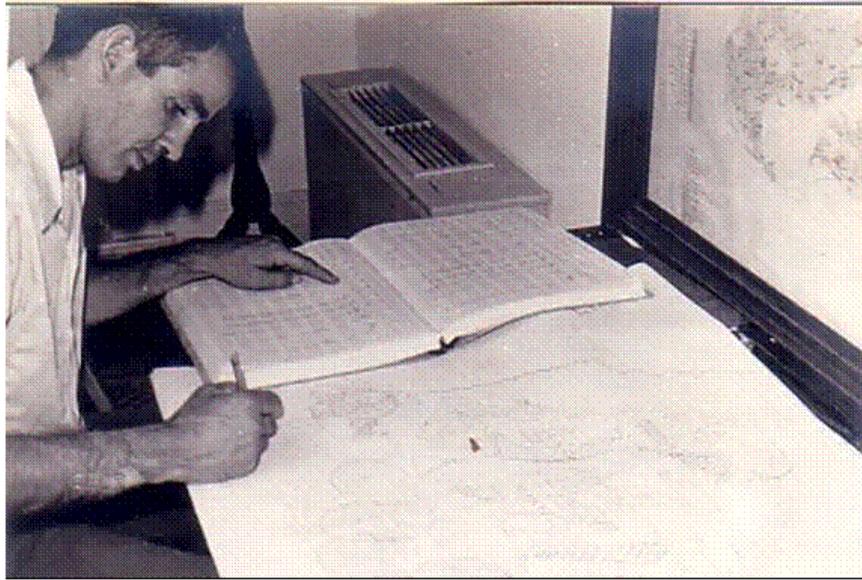


Figure 1: Don Lipscomb developing a stand inventory map manually in 1978.

uct. Don obtained USGS Digital Line Graphs of the Georgetown South and North Island Quadrangle sheets that covered Hobcaw Forest. Since he had used forest roads as compartment boundaries, he could geo-reference his aerial photo derived stand map to the 1927 North American Datum. Since there were road intersections distributed across the property the resulting stand map removed much of the distortions found in the aerial photo mosaic. Although the lack of a file output option of the TVA-IP, required him to fill the INFO table by hand; by 1988 he had a fully functional GIS linked inventory of Hobcaw Forest. Not only was it a fully functional GIS, but it ran on a desktop computer system that cost under \$10,000. Don shared the techniques he developed locally in the Southern Silvicultural Symposium in 1989 (Lipscomb and Williams, 1989) and more widely in the ASPRS Symposium Resource Technology in 1990 (Lipscomb and Williams, 1990).

The forest inventory GIS has migrated from ArcInfo coverage, to ArcView shapefile, to ArcGIS 8, 9, 10 Geodatabase layer and an updated version is still being used in management of Hobcaw Forest today. One, very important, update occurred in 1988 and early 1989; the Georgetown County Assessor's Office prepared a large scale ortho-mosaic of the entire county. Using ERDAS-ArcInfo Live Link, Don was able to rectify the Hobcaw Forest stand map to that ortho-mosaic to produce a map in North American Datum 1983, State Plane Coordinate System that has been compatible with imagery and map products produced by all government agencies and most private corporations. One of Don's contributions to SOFORGIS '96 grew from examination of archived aerial photographs with the help of this geo-referenced base (Williams and Lipscomb, 1996).

The inventory map proved its value on September 23, 1989 when Hurricane Hugo made landfall roughly 50 miles SE of Hobcaw Forest. A collaboration of Clemson University and University of South Carolina researchers quickly began a series of studies to quantify the damage done by wind and saltwater surge to the forest. The GIS was used to locate a series of stratified random sample plots to assess wind damage (Gresham et al., 1991), one of the first international papers on hurricane wind damage to a temperate forest. Longer term mortality due to saltwater from the storm surge was determined by aerial photographs taken in October 1989, June 1990, and October 1991 and 1992. The stand map and orthophotography layer Don had produced were used to georeference tree mortality on these photographs (Gardner et al., 1991). Since Don had made a geo-referenced base, the map of tidal surge mortality can be overlaid on much later LiDAR DEM data (Williams et al., 2013) and compared to a well quantified surge of Hurricane Matthew in 2016 (O'Halloran et al., 2019).

Another outgrowth of the inventory layer and historical aerial photography was an effort to accurately visualize past forest conditions (Williams et al., 2005). We used Don's aerial photo interpretation skills in an early attempt to map tree stems from large scale aerial photos. By combining the stem map estimation with stand data from the 1986 inventory we could produce a movie of a scenic portion of the forests that had been decimated by the hurricane. We were able to pull a still frame from that movie that reproduced a scenic photo taken in 1978. Don's early work on geo-rectifying aerial photography proved useful to visualization of the forest.

3 Red-Cockaded Woodpecker (RCW)

3.1 Habitat Mapping

Hobcaw Forest, like the nearby Francis Marion National Forest, had the densest population of RCWs in the nation when the species was added to the Endangered Species List (Lennartz et al., 1979). Gene Wood mapped the groups of RCW on Hobcaw Forest (Wood et al., 1985) as part of the original research leading to formulating guidelines for RCW management on federal lands. Those maps and a complete search of the forest trees during the 1986 forest inventory were used to locate RCW trees throughout the forest. Don then mapped each RCW cavity tree on the forest with transit and tape from known points in the GIS, creating an RCW cavity tree data layer that is still in use.

Don completed the mapping of RCW trees in August of 1989. As with his inventory map layer, the RCW tree layer was instrumental to a rapid assessment of the impact of Hurricane Hugo on survival of RCW cavity trees. By late October of 1989, Don had visited each tree and noted survival or mode of mortality. That survey could be directly compared to the whole forest data collected by Gresham et al. (1991) to find that RCW cavity trees four times more likely to be broken or wind-thrown by hurricane winds than the general forest population (Lipscomb and Williams, 1995b). The larger old growth pines

RCW chose as cavity trees were more likely to be damaged than younger trees and cavity trees were twice as likely to break as other tree that were matched by species and diameter.

The orthophoto based inventory map became essential to examining the recovery of the RCW population after the hurricane. In the early 1990's, GPS was expensive and imprecise in the forest. As the woodpeckers excavated new cavity trees the simplest method to establish a location was to use large scale aerial photography that was being taken after the hurricane and rectify that to the orthophoto map. Large scale rectified prints could be carried to the forest and new cavity trees marked on those by aerial photo interpretation. The rate of recovery, spatial pattern of recovery, and relationship of new cavity trees to potential foraging habitat could all be evaluated from these two GIS layers (Lipscomb and Williams, 1998a; Lipscomb and Williams, 1998b; Williams and Lipscomb, 2002; Williams et al., 2004).

3.2 RCW Private Landowner Guidelines

The abundance of RCW groups on Hobcaw Forest was an extreme example of the problem facing many private forest landowners and the U.S. Fish and Wildlife Service (USFWS) in the late 1980's. Management of the RCW on federal lands was guided by agreements between the USFWS and US Forest Service (Costa and Escano, 1989). However, the goal of that management was recovery of the species and focused on techniques to increase populations. That goal was not reasonable for private landowners, whose only obligation under the Endangered Species Act was to not kill the RCW. Research on the habitat requirements of RCW suggested that RCW needed specific forest conditions for survival that would be financially damaging to landowners where the woodpecker occurred. The ensuing controversy pitted USFWS regulators against many small private landowners who viewed the Endangered Species Act as an unconstitutional taking of private property rights.

When Don arrived at Clemson, he met Ralph Costa, the USFWS coordinator of RCW recovery for the Southeast. Don's experience with RCW on Hobcaw Forest and using GIS to plan management of RCW habitat, created a mutually advantageous collaboration on management of RCW habitat on private lands (Costa and Kennedy, 1994; Costa and Kennedy, 1996). His efforts to map RCW habitat on Hobcaw Forest revealed complexity of RCW habitat that was not anticipated by writers of the management guidelines (Lipscomb and Williams, 1995a). In dense populations of RCWs, GIS proved essential to define forests areas that were utilized by competing groups of RCW (Lipscomb and Williams, 1996).

Moving to Clemson allowed Don access to a Sun Sparc Station, a UNIX based workstation capable of running all features of ArcInfo. Although RCW habitat mapping was possible with PC-ArcInfo, it could not be automated without the Arc Macro Language (AML) programming language available only on the full ArcInfo implementation of the UNIX operating system (Lipscomb and Williams, 1998a; Lipscomb and Williams, 1998b).

Don's AML program, Red Cockaded Woodpecker Forage Analysis Tool (RCWFAT) implemented the spatial rules he had proposed in the 1996 SOFORGIS proceedings (Lipscomb and Williams, 1996). Active cavity trees less than 400 feet apart were aggregated into a cluster and a preliminary center was established and active trees less than $\frac{1}{4}$ mile were aggregated into that cluster and a line was drawn connecting to the nearest cavity tree of the cluster. Single active cavity trees more than $\frac{1}{4}$ mile from any cluster were assigned as a separate cluster of one. The center of each cluster was defined as the mean x and mean y coordinates of all trees in the cluster. A preliminary forage area was determined with a $\frac{1}{4}$ buffer on the cluster center. For overlapping forage areas, a bisector of the overlap was used to partition forage area to the nearest cluster center. Don then partnered with several federal agencies to use RCWFAT to analyze RCW populations (Lipscomb and Williams, 1999; Lipscomb and Williams, 2005; Lipscomb and Williams, 2006a; Lipscomb and Williams, 2006b).

RCWFAT was fated to be a short-lived technology. When ESRI released ArcGIS 8x, AML was no longer supported as ArcObjects and Visual Basic became the norm for creating ArcGIS models. RCWFAT was used only on legacy systems with ArcInfo 7x (Lipscomb and Williams, 2005). Don had met Pat Wiefel at the 1998 SOFORGIS conference and began a collaboration using GIS to map RCW on Fort Bragg, NC. Fort Bragg had made a major commitment to managing the forests there to enhance RCW habitat (Cantrell et al., 1995). With the advent of ArcGIS 8, ESRI and the USFWS developed a new RCW forage evaluation program based on a matrix of habitat traits developed for the Sand Hills region, using the RCW population at Ft. Bragg. That ESRI extension replicated all the functionality of RCWFAT and was freely available to anyone licensed to run ArcGIS 8. Don continued his collaboration by evaluating the efficiency of that proposed matrix on existing RCW populations where data sets allowed comparison to RCW population trends to proposed matrix scores (Lipscomb and Williams, 2006a; Lipscomb et al., 2008; Kale et al., 2008). Don continued to contribute to RCW management even after his retirement in 2008 (Loeb et al., 2012).

4 Streamside Management Zones

As Don updated his skills to ArcGIS 8 programming, he applied them to forestry Best Management Practices. Don Hook, the former director of the Baruch Forest Science Institute and Don's former supervisor developed a research plan to test how well South Carolina Forestry Best Management Practices (BMPs) protected water quality during harvest and regeneration in the South Carolina Piedmont (Williams et al., 2001). The South Carolina Best Management Practices included specific practices to be applied within a streamside management zone (SMZ) that varied in width with land slope adjacent to the stream. During that research, Don mapped the streamside zones to be used in that experiment (Lipscomb, 2000). He then went on to create VB scripts that could be used to map variable width streamside management zones with ArcGIS 8x. He later

updated them to Python for applications with ArcGIS 9x. Don's scripts to map SMZ's were published in a wide variety of venues (Williams et al., 2004; Williams et al., 2003).

Dons' early work with the Georgetown County orthophotos prepared him to use digital orthophotos and LiDAR derived DEMs that became more widely available in the late 1990's and early 2000's. He found that overlaying orthophotos on his SMZ maps could be used to screen stream systems that were contaminated by agricultural and suburban nonpoint sources. Screening stream systems for SMZ incursions agreed well with water quality screening by macro-invertebrate population parameters (Williams et al., 2003). He also developed methods to identify Piedmont isolated wetlands by combining interpretation of true and false color orthophotos with DEMs (Pitt et al., 2010; Pitt et al., 2011).

5 Protected land inventory and protection

Although Don retired as a research Forester in 2008, that merely marked another path for his GIS talents. Throughout most of his career, Don developed programs that could be used by small landowners with modest computer resources. During the last project he conducted at Clemson, his focus was expanded to the entire North American Continent (Baldwin et al., 2014). Don provided GIS expertise on a project to map and assess the threats to protected lands of North America (Lipscomb and Baldwin, 2010). He combined maps of national, state and smaller governmental parks, wilderness areas, and other protected lands with non-governmental organizations that protected natural lands from encroachment by other land uses. As part of that program Don also created a model builder program that processed all the land parcels, as well as, a 10-mile buffer for each parcel, to determine land use classification for each parcel and the surrounding buffer (Leonard et al., 2014).

6 Final thoughts

Don lost a three-year battle with cancer in March of 2019. He said that he had found life to be a journey. Of that 75 year journey he spent nearly forty applying GIS to forestry in the southeastern US. During much of that time he also demonstrated how much GIS analysis could be accomplished with less than \$10,000 of computer equipment. His career, in many ways like the Southern Forestry GIS Conferences, was dedicated to helping practicing foresters with technology that could improve their work.

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References

- Baldwin, R., R. Scherzinger, D. Lipscomb, M. Mockrin, and S. Stein. 2014. Planning for land use and conservation: Assessing GIS-based conservation software for land use planning. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Research Note RMRS-RN-70. 33p.
- Bean, S.D., and B.K. Ellis. 1984. User manual for Tennessee Valley Inventory Processor System. Tennessee Valley Authority, Norris, TN. 56 p.
- Cantrell, M.A., J.J. Britcher, and E.L. Hoffman. 1995. Red-cockaded woodpecker management initiatives at Fort Bragg military installation. In Red Cockaded Woodpecker Symposium III: Species Recovery, Ecology and Management, Kulhavy, D.L., R.G. Hooper, and R. Costa (eds.). Stephen F. Austin State University, Center for Applied Studies in Forestry, Nacogdoches, TX. pp. 89-97.
- Costa, R., and R.E.F. Escano. 1989. Red-cockaded woodpecker: status and management in the southern region in 1986. U.S. Department of Agriculture, Forest Service, Southern Region, Atlanta, GA. Technical Publication R8-TP12.
- Costa, R., and E. Kennedy. 1994. Red-cockaded woodpecker translocations 1989-1994: State-of-our-knowledge. In Annual Proceedings of the American Zoo and Aquarium Association. Zoo Atlanta, Atlanta, GA. pp. 74-81.
- Costa, R., and E.T. Kennedy. 1996. An incentive program to enhance conservation of longleaf pine and red-cockaded woodpeckers on private land: The case of safe harbor. In Proceedings of the First Longleaf Alliance Conference. Longleaf Pine: A Regional Perspective of Challenges and Opportunities, Kush, J.S. (comp.). The Longleaf Alliance, Auburn, AL. pp. 30-33.
- Gardner, L. R., W.K. Michner, E.R. Blood, T.M. Williams, D.J. Lipscomb, and W.H. Jefferson. 1991. Ecological impact of Hurricane Hugo- salinization of a coastal forest. *Journal of Coastal Research* SI 8:301-317,
- Gresham, C.A., T.M. Williams, and D.J. Lipscomb. 1991. Hurricane Hugo wind damage to Southeastern U S coastal forest tree species. *Biotropica* 24:4 420-427.
- Kale, A., T.M. Williams, B. Song, D.J. Lipscomb, and R. Costa. 2008. Application of GIS Model in Evaluating the Red-Cockaded Woodpecker Habitat at Hobcaw Barony. In Proceedings of the 6th Southern Forestry and Natural Resources GIS Conference, Bettinger, P., et al. (eds.). Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA. pp. 223-236.
- Lennartz, M. R., R. G. Hooper, and R. F. Harlow. 1979. The red-cockaded woodpecker: management research needs. In Proceedings of the First South

- Carolina Endangered Species Symposium, Forsythe, D.M., and W.B. Ezell Jr. (eds.). South Carolina Wildlife and Marine Resources Department, Columbia, SC. pp. 151-158.
- Leonard, P.B., R.F. Baldwin, E.B. Duffy, D.J. Lipscomb, and A.M. Rose. 2014. High-throughput computing provides substantial time savings for landscape and conservation planning. *Landscape and Urban Planning*. 125: 156-165.
- Lipscomb, D.J. 2000. An Arc/Info program to model stream management zones as defined by South Carolina Best Management Practices. In *Proceedings of the 3rd Southern Forestry GIS Conference*, Hubbard, W.G., and J.B. Jordan (eds.). University of Georgia, Athens, GA. 13 p. Available online at http://soforgis.uga.edu/files/2000/Lipscomb_SOFORGIS_Final.2000.pdf
- Lipscomb, D.J., and R.F. Baldwin. 2010. Geoprocessing solutions developed while calculating Human Footprint™ statistics for zones representing protected areas and adjacent lands at the continent scale. *Mathematical and Computational Forestry & Natural-Resource Sciences*. 2(2): 138-144.
- Lipscomb D.J., A. Kale, T.M. Williams, and B. Song. 2008. GIS contribution to Red-Cockaded Woodpecker habitat management: Benefits and remaining problems. In *Proceedings of the 6th Southern Forestry and Natural Resources GIS Conference*, Bettinger, P., et al. (eds.). Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA. pp. 251-263.
- Lipscomb, D.J., and T.M. Williams 1989. Micro-computer map based data retrieval system for forest managers. In *Proceedings of the Fifth Biennial Southern Silvicultural Research Conference*, Miller, J. H. (comp.). U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA. General Technical Report SO-74. pp. 219-224.
- Lipscomb, D.J., and T.M. Williams. 1990. Developing a GIS for forest management in the 1990's. In *Resource Technology 90: Second International Symposium on Advanced technology in Natural Resource Management*. American Society of Photogrammetry and Remote Sensing, Bethesda, MD. pp. 551-560.
- Lipscomb, D.J., and T.M. Williams. 1995a. Use of geographic information systems for determination of red cockaded woodpecker management areas. In *Red Cockaded Woodpecker Symposium III: Species recovery, Ecology and Management*, Kulhavy, D.L., R.G. Hooper, and R. Costa (eds.). Stephen F. Austin State University, Center for Applied Studies in Forestry, Nacogdoches, TX. pp. 137-145.
- Lipscomb, D.J., and T.M. Williams. 1995b. Impact of Hurricane Hugo on cavity trees of a red cockaded population and natural recovery after two and a half years. In *Red Cockaded Woodpecker Symposium III: Species recovery, Ecology and Management*, Kulhavy, D.L., R.G. Hooper, and R. Costa (eds.). Stephen F. Austin State University, Center for Applied Studies in Forestry, Nacogdoches, TX. pp. 167-172.

- Lipscomb, D.J., and T.M. Williams. 1996. A technique for using PC-ARC-INFO GIS to determine red cockaded woodpecker foraging areas on private lands. In Proceedings of the Southern Forestry Geographic Information Systems Conference, Arthaud, G.J. and W.C. Hubbard (eds.). University of Georgia, Athens GA. pp. 255-264.
- Lipscomb, D.J., and T.M. Williams. 1998a. RCWFAT an ARC-INFO AML program to assist in evaluating RCW foraging. In Proceedings of Southern Forestry Geographic Information Systems Conference. University of Georgia, Athens, GA. pp 43-56.
- Lipscomb, D.J., and T.M. Williams. 1998b. Spatial changes in RCW management constraint areas over a ten year period on Hobcaw Barony. In Proceedings of Southern Forestry Geographic Information Systems Conference. University of Georgia, Athens, GA. pp. 57-68.
- Lipscomb, D.J., and T.M. Williams. 1999. RCWFAT an ARC/INFO AML program to assist in evaluating RCW habitat requirements. In Proceedings of the Tenth Biennial Southern Silvicultural Research Conference, Haywood, J.D. (ed.). U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. General Technical Report SRS-30. pp. 614-616.
- Lipscomb, D.J., and T.M. Williams. 2005. Examining RCW management changes in the 2003 recovery plan using habitat mapping. In Proceedings of the 4th Southern Forestry and Natural Resources GIS Conference, Bettinger, P., et al. (eds.). Warnell School of Forest Resources, University of Georgia, Athens, GA. pp. 27-36.
- Lipscomb, D.J., and T.M. Williams. 2006a. Evaluating some proposed matrices for scoring suboptimal red-cockaded woodpecker foraging habitat in relation to the 2003 recovery plan. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. General Technical Report SRS-92. pp. 10-16.
- Lipscomb, D.J., and T.M. Williams. 2006b. A GIS tool for evaluating the impact of proposed cuts on red-cockaded woodpecker habitat. In Proceedings of the 5th Southern Forestry and Natural Resources GIS Conference, Prisley, S., et al. (eds.). Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA. pp. 139-147.
- Loeb, S.C., S.L. Reid, and D.J. Lipscomb. 2012. Habitat and landscape correlates of southern flying squirrel use of red-cockaded woodpecker clusters. *Journal of Wildlife Management*. 76(7): 1509-1518.
- O'Halloran, T.L., T.M. Williams, E.M. Smith, D. Mishra, S. Whitmire, B. Song, S. Van Bloem, and W. Conner. 2019. Observations of pulse and press disturbances in North Inlet, South Carolina.. American Geophysical Union Fall meeting, San Francisco, CA, December 9-13, 2019.

- Pitt, A.L., R.F. Baldwin, B.L. Brown, J.E. Hawley, D.J. Lipscomb, and C.M. Allard. 2010. Does the South Carolina upstate have 'isolated wetlands' and how do they function? A preliminary analysis. In Proceedings of the 2010 South Carolina Water Resources Conference. Available at: <https://tigerprints.clemson.edu/scwrc/2010/2010management/13/>. Accessed 4 March 2020.
- Pitt, A.L., R.F. Baldwin, D.L. Lipscomb, B.L. Brown, J.E. Hawley, C.M. Allard-Keese, and P.B. Leonard. 2011. The missing wetlands: using local ecological knowledge to find cryptic ecosystems. *Biodiversity and Conservation* 21(1): 51-63.
- Williams, T.M., D.D. Hook, and D.J. Lipscomb. 2001. Results of voluntary forest management guidelines to protect water quality in the Southeastern US: An example for South Carolina. In *Bioenergy from sustainable forestry: Principles and Practice*, Richardson, J. et al. (Comps.). New Zealand Forest Research Institute, Forest Research Bulletin 223. pp. 71-81.
- Williams T.M., and D.J. Lipscomb. 1996. Incorporating historical aerial photography into a rectified GIS forest inventory system. In Proceedings of the Southern Forestry Geographic Information Systems Conference, Arthaud, G.J. and W.C. Hubbard (eds.). University of Georgia, Athens GA. pp. 292-301.
- Williams, T.M., and D.J. Lipscomb. 2002. Natural recovery of red-cockaded woodpecker cavity trees after Hurricane Hugo. *Southern Journal of Applied Forestry*. 26(4): 197-206.
- Williams, T.M., D.J. Lipscomb, and G.K. Chastain. 2004. Changes in status of cavity trees on the Hobcaw Forest between 1989 and 2001. In *Red-cockaded woodpecker: Road to recovery*, Costa, R., and S.J. Daniels (eds.). Hancock House, Surry, BC. pp. 439-453.
- Williams, T.M., D.J. Lipscomb, W.R. English, and C. Nickel. 2003. Mapping variable-width streamside management zones for water quality protection. *Biomass and Bioenergy*. 24: 329-336.
- Williams, T.M., D.J. Lipscomb, and C.J. Post. 2004. Defining streamside management zones or riparian buffers. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. General Technical Report SRS-71. pp. 378-383.
- Williams, T.M., B. Song, and D.J. Lipscomb. 2005. Visualization of past forest conditions from historical aerial photography. In Proceedings of the 4th Southern Forestry and Natural Resources GIS Conference, Bettinger, P., et al. (eds.). Warnell School of Forest Resources, University of Georgia, Athens, GA. pp. 138-147.

- Williams T.M., B. Song, C.C. Trettin , and C.A. Gresham. 2013. A Review of Spatial Aspects of Forest Damage and Recovery on the South Carolina Coast Following Hurricane Hugo. *Journal of Geography of Natural Disasters*. 3: 110. doi:10.4172/2167-0587.1000110
- Wood, G.W., L.J. Niles, R.M. Hendrick, J.R. Davis, and T.L. Grimes. 1985. Compatibility of even-aged timber management and red-cockaded woodpecker conservation. *Wildlife Society Bulletin*. 13(1): 5-17.