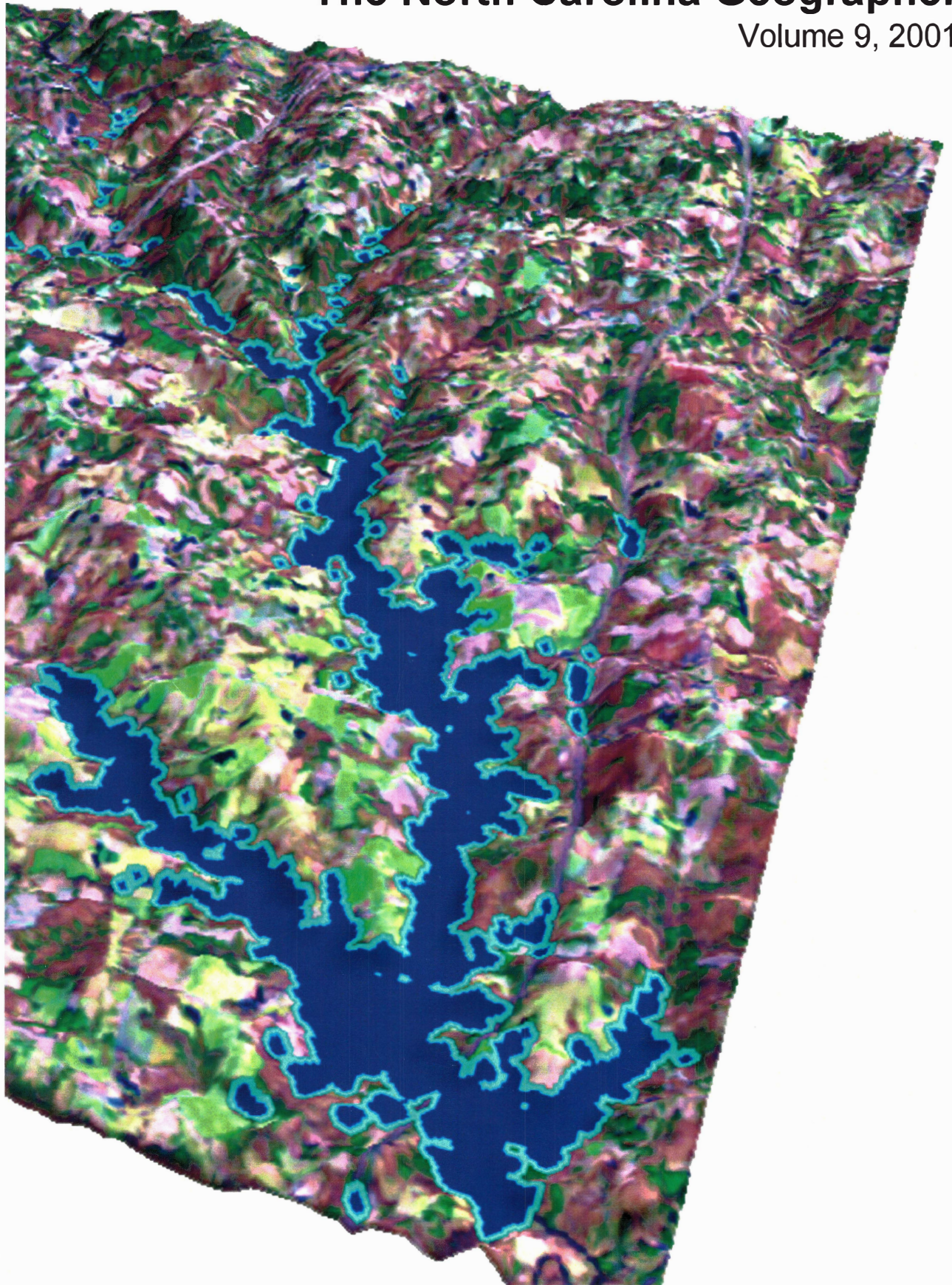


The North Carolina Geographer

Volume 9, 2001





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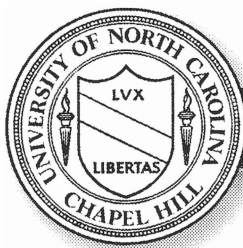
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About the Cover

Landsat Thematic Mapper (TM) data, and future Randleman Reservoir (blue) and 200 ft. erosion/pollution control buffers (cyan) around the Reservoir were draped over the United States Geological Survey (USGS) digital elevation model (DEM) data. The viewpoint is above the Dam site and is looking up stream along Deep River and Muddy Creek. Different colors on the surrounding hills represent different land use and land cover types in the area. I-220 is noticeable on the right. Isolated polygons or "ponds" in the Reservoir were caused by the coarse spatial resolution and uncertain vertical resolution of the DEM data. For more information about this image, see the article in this issue by Yong Wang and Scott Wade.



DEPARTMENT of GEOGRAPHY

<http://www.unc.edu/depts/geog>

The University of North Carolina at Chapel Hill is the oldest state university in the country and is recognized as one of the nation's premiere public institutions, with extensive and state-of-the-art resources and a range of nationally and internationally recognized academic programs. Set within this environment is Geography, a collegial, dynamic, and highly productive department of 19 faculty that has recently been targeted by the University administration for growth and development. This support has resulted in nine faculty hires since 1997, including five senior faculty, two of whom occupy named professorships and a third who is Dean of the College of Arts and Sciences. Geography offers the B.A., M.A., and Ph.D. degrees, with most of the 45 graduate students pursuing the doctorate.

Undergraduate Program. The department offers a broadly based B.A. degree with concentration in three areas: the geography of human activity, earth environmental systems, and geographic information sciences. A well-equipped teaching lab directly supports undergraduate teaching and research, and a range of state-of-the-art facilities can be found at several venues on campus.

Graduate Program. The graduate program reflects the ongoing commitment to the highest quality research and the intention to continue to direct resources toward primary research strengths: Critical Geography, Earth Systems Science, and Geographical Information Sciences, with overall emphases toward environmental studies and global/local processes. These areas are highly integrated in individual and group research projects, while interdisciplinary cooperation is also highly valued.

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Earth Systems Science. Research focuses on the interplay between climate, vegetation and hydrology in a variety of environments. Current projects include spatial modeling and analysis of climate-vegetation patterns in mountain environments; tree-line dynamics; large scale precipitation patterns; inter-decadal climate/ecosystem feedbacks; forest water, carbon and nutrient cycling; watershed processes; and urban ecosystems. State-of-the-art techniques in remote sensing, spatial analysis, and modeling are used, and there are a variety of funded projects, including several major NSF Long Term Ecological Research sites.

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Using Digital Spatial Data Sets to Study the Impact of Reservoir Construction on Local Environment and Community

Yong Wang and Scott Wade

Center for Geographic Information Science and Department of Geography
East Carolina University

Digital spatial and demographic data sets have been used to study the impact of the Randleman Reservoir on the local environment and demography of Randolph and Guilford counties, N.C. At surface water heights of 682, 685, 706, and 709 ft. above the mean sea level, the reservoir's capacities were 25,053, 29,242, 92,654, and 106,654 acre-ft., and total surface areas (reservoir plus 200ft. erosion/pollution control buffers) 3,081, 3,516, 7,403, and 8,233 acres, respectively. The capacities and total surface areas were lower than those reported in the environmental impact statement by the U.S. Army Corps of Engineers and those published at the Piedmont Triad Regional Water Authority's Web page. These underestimations were attributed to the inaccurate representation of the digital elevation model (DEM) data used. After applying a 3 by 3 minimum spatial filter to the DEM data, the recomputed reservoir capacities and areal extents were very close to those reported and published as mentioned in the above. At the surface water heights of 682 and 706 ft., the recalculated capacities were 52,445 and 162,709 acre-ft., and reservoir (only) areas 2,958 and 7,035 acres, respectively.

Introduction

Great effort has been made to create spatial and demographic data sets for documenting and studying the physical and social environments in the United States. These data sets include elevation data, satellite imagery, landuse and land cover types, digital aerial photography, political and statistical boundaries, streets and highways, as well as population and other demographic statistics. Most of the data are available for free or for very little cost (with the exception of satellite imagery) from U.S. government agencies like the U.S. Geological Survey (USGS) and the U.S. Census Bureau, and much of it can be conveniently downloaded from the Internet.

Due to the rapid development in computer technology, varieties of GIS software for desktop/laptop computers are widely available. The leading GIS software includes ArcView, ArcInfo, and recently ArcGIS (Environment System Research Institute, ESRI, California), IDRISI (Graduate School of Geography, Clark University), MapInfo (MapInfo Corporation of Troy, New York), and others (Clarke 2001). The software products have easy-to-use graphical user interfaces. They are reasonably priced and widely used in schools, government agencies, and the private sector. University geography departments use the products to teach geographic information science to students, many of whom decide to pursue

undergraduate and graduate degrees in geography. Students from other disciplines (e.g., biology, geology, and business) are also learning to use GIS software in order to enhance their technical research skills.

Having briefly discussed the development and availability of digital spatial data sets and GIS software, we next present an example of how they can be used to study a regional planning problem in North Carolina. After years of planning and preparation of environmental impact studies by governmental agencies and private companies (e.g., Moore and Leonard 1973, Weiss et al. 1973, Black and Veatch 1988, 1990, Lautzenheiser et al. 1997, U.S. Army Corps of Engineers 2000a), the construction of the Randleman dam and reservoir started in Summer 2001. If all goes as planned, the reservoir will be filled by 2004 (<http://www.ptrwa.org>). The future reservoir will provide water to the Piedmont Triad Regional Water Authority's (PTRWA) six members: Greensboro, High Point, Jamestown, Archdale, Randleman, and Randolph County.

Analysis

The objectives are to: 1) estimate the reservoir capacity produced by the dam project; 2) calculate the surface area of the reservoir and its 200 foot erosion/pollution control buffer; 3) determine the landuse and land cover types inundated by the reservoir; and

4) study the impact of the reservoir on human settlement/resettlement in the area. All of the above will be addressed at two conservation pool and two flood pool surface heights.

Study area

The dam site is situated on the Deep River about 2 miles northwest of the City of Randleman, NC. The reservoir will be mainly along the Deep River (upstream), and also partially along Muddy Creek (Fig. 1). When the surface water height is at 682 ft. (the conservation pool), the reservoir's water will be back up about 13 miles along the Deep River, almost to I-85. When the reservoir is at the surface water height

of 706 ft. or its flood pool, the water will reach the City of Jamestown, NC.

Spatial and demographic datasets

a) *DEM data.* As a part of the National Mapping Program, the USGS led the creation of the DEM data set with coverage for the entire United States and its territories. DEMs are digital elevation data that consist of arrays of elevations in x and y directions and are sampled at regularly spaced intervals (cells). An elevation (z) value of a cell is sampled from elevation values of all locations within the cell, and is measured based on the mean sea level. DEMs are used for presenting and studying the topography of ground

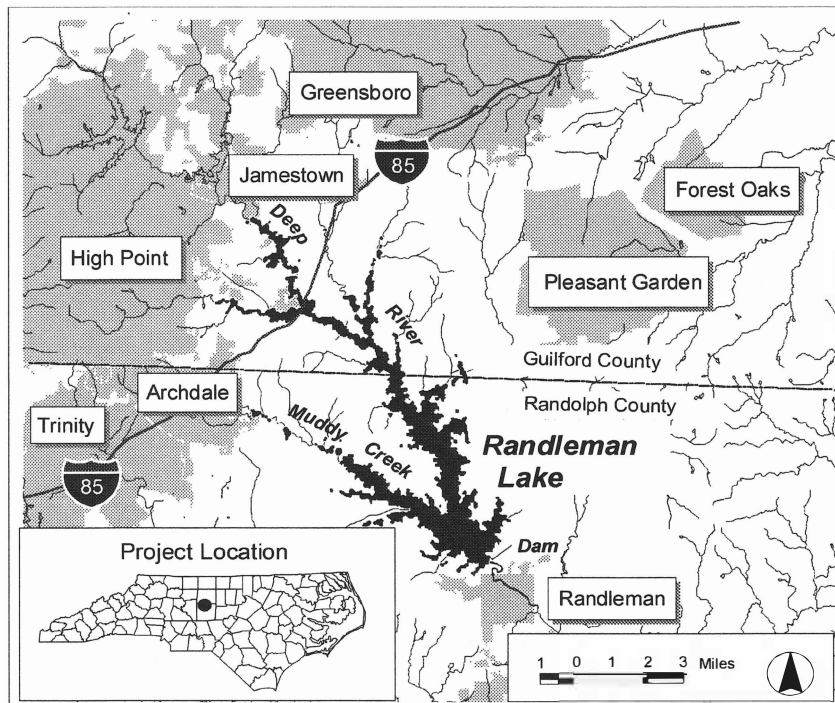


Figure 1. The future Randleman Reservoir and its surroundings in Guilford and Randolph counties, NC.

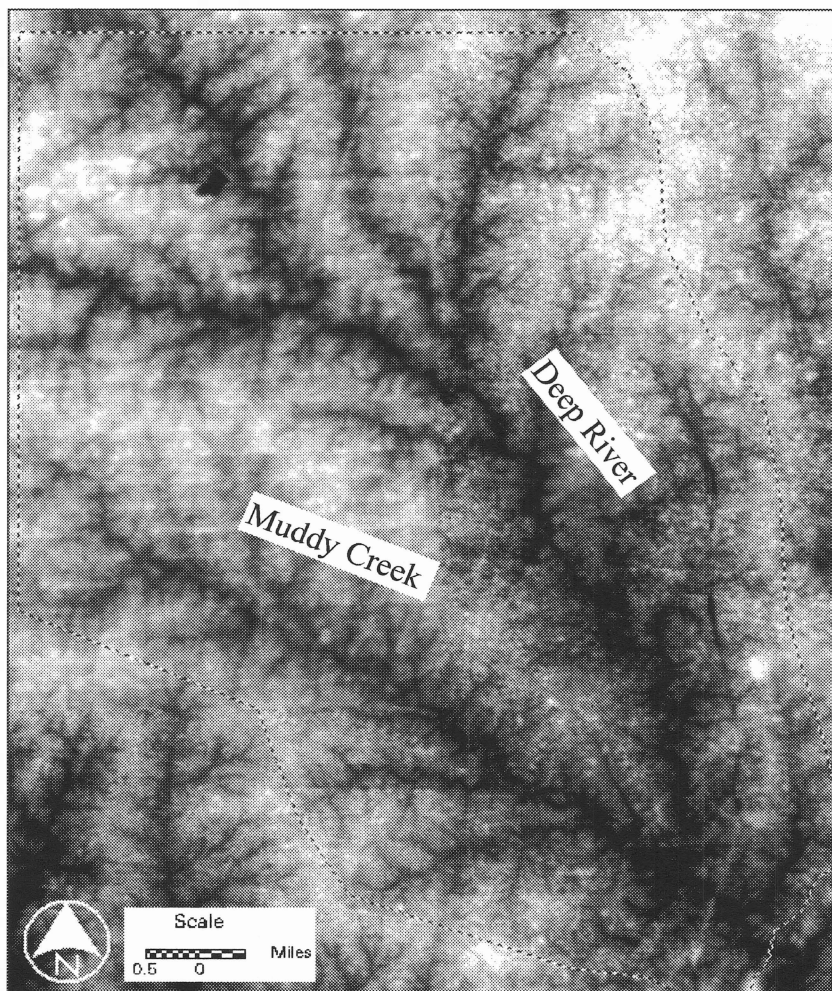


Figure 2. DEM for Randleman Reservoir. The dark areas show low elevation, and bright areas high elevation. The area of interest (AOI) is outlined.

surface, and for hydrological modeling of a local watershed or even an entire river-basin (e.g., U.S. Army Corps of Engineers 1986, 2000b). The DEMs (of the U.S.) are freely downloadable (<http://edcwww.cr.usgs.gov/doc/edchome/ndcldb/ndcldb.html>). The DEMs used were at 1:24,000 scale with a cell size (x, y) of 30 m by 30 m. The accuracy of the z value is less than or equal to $\pm$ of the contour lines on the USGS 7.5 minute quadrangle or 5 ft. in the study area. Fig. 2 shows the local topography, with black indicating low elevation and white high elevation.

The area of interest (AOI) covering the future reservoir and its surrounding areas is also outlined.

b) *Landsat TM data (the background in figure 4).* Landsat is a series of satellites developed and sent into space by the NASA. The Landsat program dates back to the early 1970s. Landsat 7 launched in 1999 along with Landsat 5 are two Landsat satellites still in operation. Using its onboard remote sensors, Landsat collects information about the earth's surface. One of the sensors is the Thematic Mapper (TM), which measures the reflectance of surface targets on earth

illuminated by the solar radiation in the visible and infrared wavelength range or in a portion of electromagnetic spectrum. TM data are distributed as digital images, each of which covers an area of approximately 180 km by 180 km, or 32,400 km². The cell (pixel) sizes of TM sensor onboard Landsat 7 are 30 m by 30 m for bands 1-5 and 7, 60 m by 60 m for band 6, and 15 m by 15 m for band 8. The pixel sizes of Landsat 5's TM are 30 m by 30 m for bands 1-5 and 7, and 120 m by 120 m for band 6. The TM data are available from the USGS's EROS data center in South Dakota, EOSAT Company in Maryland, or SpaceImaging Corporation in Colorado. The cost of the Landsat 5 or 7 TM data varies. One Landsat 7 TM image ordered from the USGS costs about \$600.00, and a Landsat 5 TM image ordered from the SpaceImaging Corporation ranges from \$600 to \$1675 depending on levels of processing required by a customer (<http://www.spaceimaging.com>). TM data as well as remotely sensed data collected by other satellites have been widely used to study the earth's environment (e.g., Verbyla 1995, Jensen, 2000).

c) *Landuse and land cover type data.* The data were derived mainly from the Landsat 5's TM data, coupled with ground observation and other available ancillary information. They were used to quantify each landuse and cover type to be inundated by the construction of the Randleman dam. In the reservoir region, there are 13 landuse and land cover types, ranging from high intensely developed urban area to different types of natural and vegetated surfaces; as well as open water (see Table 2 for other landuse and land cover types). Landuse and land cover types in small areas or patches of small areas might not be identified within the data because the pixel size of the data was 30 by 30 m.

d) *High resolution digital orthophoto quadrangle (DOQ) data.* These are digital photographic images with a resolution of 1 m by 1 m. Panchromatic DOQs created by the USGS in the early 1990s can be freely downloaded from the Microsoft TerraServer (<http://terraserver.microsoft.com>) at a degraded spectral resolution. Higher quality (panchromatic) originals, as well as false color infrared DOQs created recently (between 1997 and 1999) can be ordered from the USGS (\$60.00 per 7.5 minute quadrangle, plus CD charge and shipping). Due to its high resolution, cities,

towns, streets, and individual houses can be easily identified (Fig. 3). The DOQs downloaded from the Microsoft TerraServer were used to quantify the number of houses and man-made structures (e.g., barns) that will be inundated by the reservoir or will be within the 200 ft. buffer zone around the reservoir.

e) *Demographic and spatial data.* The U.S. Census Bureau has collected demographic data about this country for over 200 years. The largest single data collection endeavor by the Census Bureau is the decennial census of population and housing, which provides a breakdown of population, housing, and other socioeconomic variables for the national level all the way down to a geographic area equivalent to the



Figure 3. A USGS DOQ, showing individual houses, roads, trees, and vegetation in the study area.

city block. The latest decennial census was taken in 2000. The data collected in the 2000 Census is gradually becoming available, and can be downloaded for free from various Web sites (<http://www.census.gov>, <http://www.geographynetwork.com>). The Census Bureau also produces a widely utilized spatial database called TIGER (Topologically Integrated Geographic Encoding and Referencing, <http://www.census.gov>). TIGER was developed in the 1990s to produce large scale, up-to-date maps which could be used by enumerators in census taking operations. TIGER files contain streets, political boundaries, hydrography and land marks. In addition, TIGER files provide census statistical boundaries (census tracts, block groups, etc.); they are very useful for generating thematic maps of census population data. TIGER files have been converted into native and interchange formats easily read by many GIS software packages. They are distributed by county, and can be freely downloaded from the above Web sites.

Method

a) *Geo-reference the data sets.* The spatial data used were treated as information layers in a GIS. Because these layers were geo-referenced in different coordinate systems, they were reprojected to a common coordinate system before using them together. In this study, the UTM (Universal Transverse Mercator) coordinate system is used as the common coordinate system. The model of the earth's size and shape used for both location (x, y) and elevation (z) is the WGS84 (World Geodetic System – 1984) reference ellipsoid. The distance unit is the meter. (It should be noted that the NC State Plane coordinate system based on NAD83 datum is the standard system for accurate mapping in North Carolina.)

b) *Delineate the area of interest (AOI).* The AOI was delineated such that it contained both the reservoir at its highest flood pool surface height (709 ft. above the mean sea level) and the 200ft. buffer around the reservoir. The dam formed part of the AOI border, effectively excluding downstream areas from reservoir size and capacity calculations.

c) *Calculate reservoir size and capacity.* To determine the extent of the reservoir, we extracted all cells within the AOI where the DEM elevation was less than or

equal to a given reservoir water surface height. By summing the area of these extracted cells, the total area of the reservoir was computed for that given water surface height. Then, for each cell within the reservoir, a height difference between the DEM value (or bottom of the reservoir) and surface water height was calculated. The difference was then multiplied by the cell size to compute the volume (of water) in that cell location. By summing all the cell volumes reservoir capacity was estimated.

d) *Determine landuse and land cover types affected by the dam construction.* A simple overlay of the landuse and land cover type layer onto the extent of the reservoir and the buffer around the reservoir provides the information regarding which landuse and land cover types will be inundated by the reservoir, as well as which landuse and land cover types will be within the 200 ft. buffers.

e) *Count houses and other man-made structures to be impacted by the reservoir.* By overlaying the reservoir's areal extent and its buffer zone onto the DOQs, heads-up digitizing was used to identify and count houses and structures. In the future, if parcel boundaries and their corresponding real estate values are available from a county tax office, the total property value impacted by the construction of the reservoir can be calculated. (It should be also noted that census data we had at this time did not contain information about the counts of houses and other man-made structures; only the DOQ was used to count the number of houses and structures.)

f) *Estimate the number of people to be displaced by the reservoir.* Again, by overlaying the reservoir and its buffer onto the census data, the impact on the local demography was assessed. In the analysis, population figures were assumed to be uniformly distributed within each census block, and were proportionally allocated to the block pieces located within the reservoir and buffer boundaries. The estimated population of the block pieces was then summed to provide the estimated total population displaced by the reservoir.

Results

After the dam site and AOI (of the reservoir) have been identified, a model to analyze and to help understand the impact of the reservoir on the local

Table 1. Reservoir capacities and areas at four different surface heights.

Water Height (ft.)	Capacity (acre- ft.)	Reservoir Area (acre)	Buffer Area (acre)	Total Area (acre)
@ 682	25,053	1,605	1,475	3,081
@ 685	29,242	1,895	1,621	3,516
@ 706	92,654	4,465	2,938	7,403
@ 709	106,654	5,043	3,190	8,233

communities was developed. In the model, four surface water heights, 682, 685, 706, and 709 ft. above the mean sea level for the reservoir and its 200 ft. (horizontal) buffer zone were used; four reservoir sizes and capacities were computed (Table 1 and Fig. 4). The first two surface water heights (682 and 685 ft.) could be treated as the conservation pool heights, and last two as flood pool heights. (Due to uncertainty of the z value, ± 5 ft. in the DEM data used, the derived reservoir capacities and areal extents at 682 and 685 ft. could be the same, and the capacities and areal extents at 706 and 709 ft. could be the same too.) At surface water heights of 682, 685, 706, and 709 ft., the reservoir's capacities were 25,053, 29,242, 92,654, and 106,654 acre-ft., and total surface areas (reservoir plus 200 ft. erosion/pollution control buffers) 3,081, 3,516, 7,403, and 8,233 acres, respectively. Also, benefit/cost trade-offs of building the dam at lower or higher heights were evaluated. For instance, the ratios of reservoir's capacity to total affected areas (reservoir and buffers) at surface water heights of 682, 685, 706, and 709 ft. were 8.1, 8.3, 12.5, and 13.0 (acre-ft./acre), respectively. This ratio could be used as one possible trade-off indicator.

The location and areal extent of each landuse and land cover type within the reservoir and its (200 ft.)

buffer zone were identified and estimated (Table 2). The most affected landuse and land cover types were mixed upland hardwoods, managed herbaceous cover, and cultivated lands.

Using high resolution DOQs, the number of houses and man-made structures within the reservoir and its buffer zone at four surface water heights of the reservoir were counted; 82 to 321 houses and man-made structures would be affected depending on reservoir surface water height (682 ft. to 709 ft., Table 3). The ratios of reservoir capacity to the total number of houses and man-made structures within the reservoir and its buffer at surface water heights of 682, 685, 706, and 709 ft. were 305.5, 278.5, 338.2, and 332.3 (acre-ft. per number of houses and structures), respectively.

By overlaying the reservoir and its buffer onto the 2000 census block data (Fig. 5), the number of people to be displaced (Table 3) was estimated. The number of people to be affected ranged from 399 to 1376 for the surface water heights of the reservoir between 682 and 709 ft. At surface water heights of 682, 685, 706, and 709 ft., the ratios of the reservoir's capacity to the number of people to be relocated were 62.8, 62.3, 80.8, and 77.5 (acre-ft. per person),

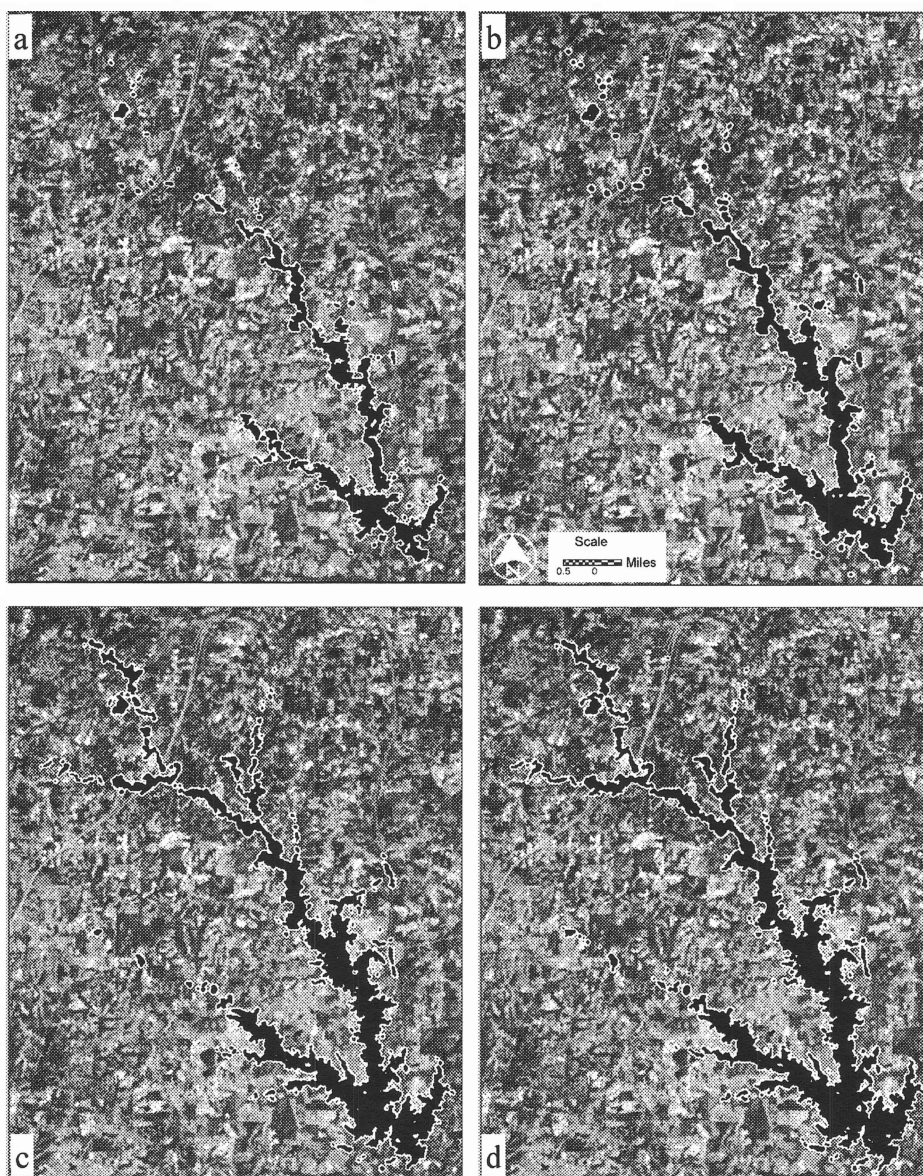


Figure 4. Randleman Reservoir (black) and its 200 ft. buffer zone (white) at water surface heights of 682 (a), 685 (b), 704 (c), and 709 (d) ft., respectively. The background for this figure was the TM image.

Table 2. Areas (acre) of each landuse and land cover type within the reservoir and erosion/pollution control buffer zone at two surface water heights.

Land use and land cover type	Water height @682 ft.			@709 ft.		
	Reservoir	Buffer	Total	Reservoir	Buffer	Total
High intensely developed urban area	29.7	29.7	59.3	93.9	81.5	175.4
Low intensely developed urban area	9.9	12.4	22.2	39.5	17.3	56.8
Cultivated land	86.5	49.4	135.9	180.4	79.1	259.5
Managed hervaceous cover	432.4	378.1	810.5	1,341.7	798.1	2,139.9
Unmanaged hervaceous cover-upland	14.8	4.9	19.8	24.7	12.4	37.1
Evergreen shrubland	12.4	4.9	17.3	17.3	4.9	22.2
Deciduous shrubland	42.0	42.0	84.0	116.1	44.5	160.6
Mixed upland hardwoods	914.3	901.9	1,816.2	3,031.9	1,989.1	5,021.0
Southern yellow pine	32.1	34.6	66.7	98.8	121.1	219.9
Other needle leaf evergreen forest	0.0	0.0	0.0	0.0	2.5	2.5
Mixed hardwoods/conifers	32.1	14.8	46.9	71.7	22.2	93.9
Water bodies	0.0	2.5	2.5	19.8	14.8	34.6
Unconsolidated sediment	0.0	0.0	0.0	2.5	2.5	4.9
<i>Total</i>	<i>1,606.1</i>	<i>1,475.2</i>	<i>3,081.3</i>	<i>5,038.3</i>	<i>3,190.0</i>	<i>8,228.3</i>

Table 3. Estimated numbers of houses and man-made structures, and people within the reservoir and buffer zone at four different reservoir surface heights.

Surface Water Height (ft)	# of houses & structures			# of people
	Within Reservoir	Within Buffer	Total	Within Reservoir & Buffer
@ 682	27	55	82	399
@ 685	37	68	68	469
@ 706	124	150	150	1,146
@ 709	139	182	182	1,376

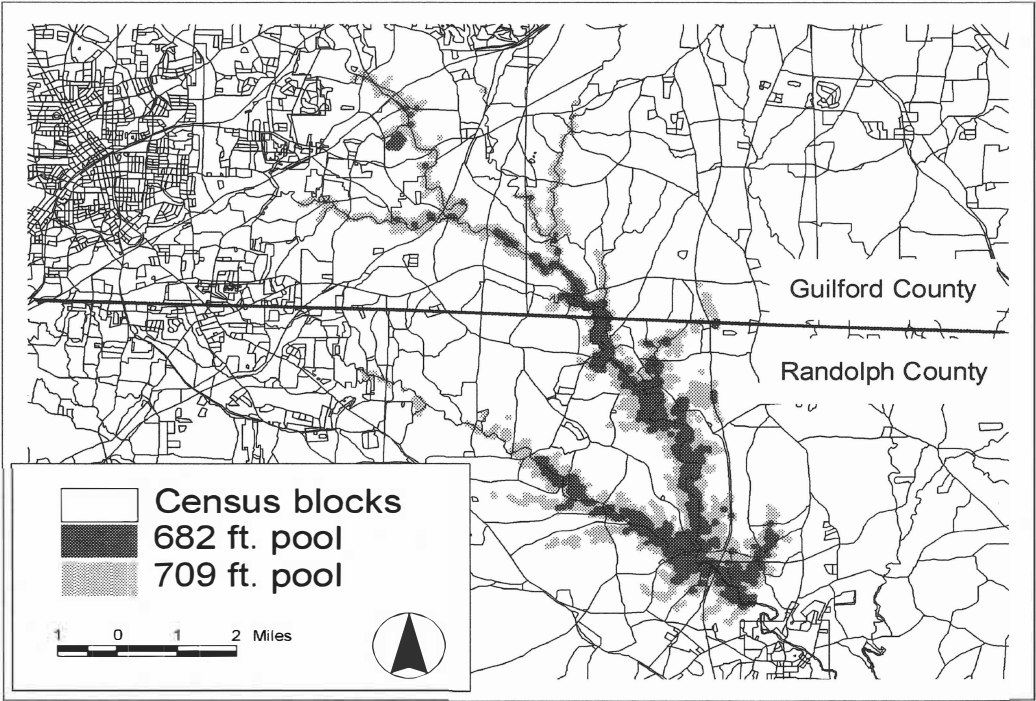


Figure 5. Reservoir and its buffers at surface water heights of 682 ft. and 709 ft. were overlaid over the Census 2000 block data; the blocks need to be redrawn before the 2010 census.

respectively. For the latter two ratios, higher values indicated that a greater volume of reservoir water was produced for each inundated house and man-made structure and for each displaced person. If the two types of ratios were used to determine the surface water height, 706 ft. would be the optimal height.

Discussion

While low cost and ease of access make digital spatial databases attractive for use in studies such as this one, they are not without limitations. For example, note the isolated reservoir polygons in Fig. 4. These polygons resulted from the coarse spatial resolution (30 m by 30 m) and uncertain vertical resolution of the DEM data. The isolated polygons were separated from each other and from the main reservoir polygon by DEM cells with sampled elevations that were higher than the respective reservoir surface water elevations. While at least a portion the ground covered by these “elevated” cells contained lower elevation streambeds, the sampled elevation for these cells was derived from the streambeds and higher ground beyond the banks of the streams when the DEM data were created (Fig. 6). Not only did this create the visually inaccurate “ponding” in Fig. 4, it was at least partly responsible for the discrepancy between the initial reservoir area and capacity estimates presented in this study and those

presented in the final environmental impact statement (EIS) (U.S. Army Corps. of Engineers, 2000a) and those at the PTRWA Web page (<http://www.ptrwa.org>) (see Tables 1 and 4). Area estimates in the EIS were calculated manually using a planimeter to trace an interpolated reservoir boundary on a topographic map. Capacity estimates in the EIS were calculated from contours on topographic maps using the *average end area method*, a technique that is commonly used to calculate volumes in engineering applications.

One method tested to remove the “ponding” and improve area and capacity estimates was to apply a minimum spatial filter to the DEM data. Reservoir surface area and capacity estimates derived from the DEM after applying a 3 by 3 minimum filter (Table 4) were remarkably improved - much closer to those stated in the final EIS and on the PTRWA Web page than the original estimates. To really understand the filtering effects and to more accurately estimate the reservoir’s area and capacity, better DEM data are required. Fortunately, better DEM data may be available soon. The USGS is currently creating higher resolution DEM data with a 10 by 10 m (x, y) resolution for the mountain and piedmont regions of North Carolina (http://mcmcweb.er.usgs.gov/status/mac/nc/nc_dem10.html). Furthermore, the State of North Carolina is creating high resolution DEM data derived

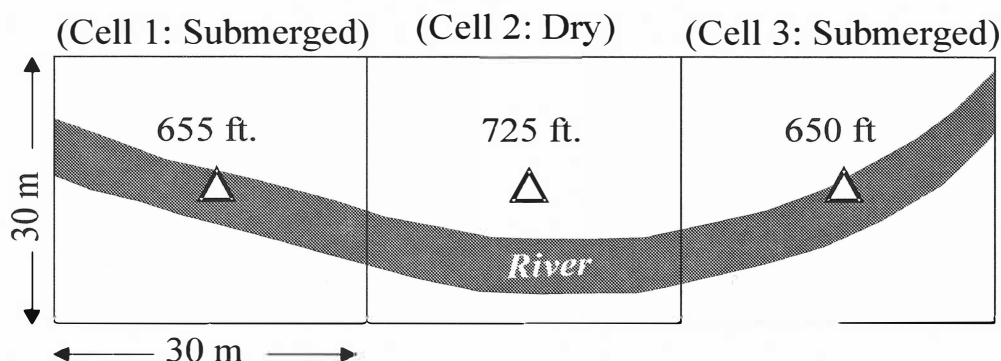


Figure 6. At a reservoir surface height of 709 ft., DEM cells 1 and 3 would be classified as submerged, but cell 2 would not be because its elevation sampled was higher than 709 ft.

Table 4. Reservoir capacities (acre-ft.) and reservoir sizes (acre) derived after applying a 3 by 3 minimum spatial filtering operation to the DEM data, reported in the environmental impact statement (EIS), and published at the Web page by the Piedmont Triad Regional Water Authority.

After spatial filtering operation			In the EIS		At the Web site	
Surface Water Height (ft.)	Capacity	Size	Capacity	Size	Capacity	Size
@ 682	52,445	2,958	62,000	3,200	--	3,007
@ 706	162,709	7,035	160,000	6,200	--	--

from LIDAR (Light Detection and Ranging) data (Dorman, 2000).

Another potential problem involved the estimation of displaced population using census block population. The proportional allocation method used assumed that the population was evenly distributed throughout the census block. If the population was unevenly distributed in reality, then the estimates of the total displaced population could be inaccurate. While it was beyond the scope of this study, the only way to accurately estimate displaced population was to conduct a field enumeration of the population within the proposed reservoir boundary.

Concluding remarks

Digital spatial and demographic data sets have been used to study the impact of the Randleman Reservoir on the local environment and demography of Randolph and Guilford counties, N.C. At surface water heights of 682, 685, 706, and 709 ft. above the mean sea level, the reservoir's capacities were 25,053,

29,242, 92,654, and 106,654 acre-ft., and total surface areas (reservoir plus 200ft. erosion/pollution control buffers) 3,081, 3,516, 7,403, and 8,233 acres, respectively. The capacities and total surface areas were lower than those reported in the final environmental impact statement by the U.S. Army Corps of Engineers and those published at the Piedmont Triad Regional Water Authority's Web page. These underestimations were attributed to the inaccurate representation of the digital evaluation model (DEM) data used. After applying a 3 by 3 minimum spatial filter to the DEM data, the recomputed reservoir capacities and areal extents were very close to those reported and published as mentioned in the above. At the surface water heights of 682 and 706 ft., the recalculated capacities were 52,445 and 162,709 acre-ft., and reservoir (only) areas were 2,958 and 7,035 acres, respectively.

The most affected landuse and land cover types due to the construction of the reservoir were mixed

upland hardwoods, managed herbaceous cover, and cultivated lands.

This study has demonstrated the potential of using geo-referenced spatial and demographic datasets once they have been integrated into a GIS. Also, these datasets are available to the public at little or no cost. With a general background in geographic information science and training in the use of remote sensing/GIS software, many users can carry out studies incorporating the spatial and demographic data sets relevant to their sub-fields, and can generate many eye-opening applications in the near future.

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Hurricanes and Snow: A Common Occurrence in Eastern North Carolina?

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Snowfall is a rare occurrence in eastern North Carolina, yet rain is plentiful in summer and fall due to thunderstorms and tropical systems. The image of hazards created by both hurricanes and snow are uncommon to North Carolinians due to the climate of the region. However, just as recently as 1999, eastern North Carolina was faced with the challenge of responding first to a hurricane hazard (Dennis and Floyd) then record snowfalls the following winter. The purpose of this paper is to create a baseline-climatology, including frequency, probability, and magnitude, for the occurrence of record hurricane seasons followed by record snow seasons in eastern North Carolina. Results indicate that the occurrence of record rainfall created by a tropical systems followed by a record snowfall in the following is actually fairly common, 18 out of 52 hurricane-snow seasons. The conditional probability of a record snow occurring if a record rain occurs in the preceding hurricane season is 0.95. The authors believe that a physical process does not create the high probability of record rain and snow, but is a fallacy created by the database structure. In particular, a relatively short period of record causes record rain and snow to be likely during the hurricane or snow season. Through an increase of the period of record, a more accurate characterization of a record hurricane-snow season may be possible.

Introduction

North Carolina is classified as a Humid Subtropical climate (Koeppen, Cfa) (Critchfield, 1983). This climate type is characterized by a hot, sultry summer similar to the rainy tropics, and mild winters with occasional frost and snow produced by frontal storms (Lutgens and Tarbuck, 2001). Despite this classification, not all of North Carolina closely follows this climate type description (Soule, 1996). In particular, the mountains of western North Carolina experience cool summers and annual snow totals as much as 117 cm. To the east, the Piedmont and the Coastal Plain experience weather closest to the Cfa description. Snowfall is rare in these areas, yet precipitation is plentiful in summer and fall due to thunderstorms and tropical systems.

It is well documented that the tropical systems not only provide plentiful rain to eastern North Carolina but they also represent the leading natural hazard (Barnes, 1995; Hidore and Patton, 1996). An example of this type of hazard occurred in the summer of 1999 when Hurricanes Dennis and Floyd made landfall along the North Carolina coast (NWSILM, 1999). Floyd was the larger of the two hurricanes and caused record rainfalls and flood stages across the

eastern portion of the state (Gares, 1999). Some assessments of the floods created by Hurricane Floyd suggest a 500-year recurrence interval event (Lecce, 2000). The hurricanes and floods caused millions of dollars in damage and disrupted society for months after their passage (NWSILM, 1999).

Given the magnitude and amount of damage created by Hurricanes Dennis and Floyd, many people forget the other weather hazard that occurred the following winter and disrupted society across eastern North Carolina. A total of nine daily snowfall records were set during January 2000. The greatest snowfalls occurred on January 25, 2000 when Raleigh received 17.9 inches and Wilmington received 5.0 inches. These snowfalls required expensive response activities and caused the city of Raleigh to virtually shutdown.

The weather hazards of 1999 indicate that despite a Cfa climate in eastern North Carolina, it is possible for a hurricane to be followed by snow the next winter. Since snow is rare in eastern North Carolina, this rarity causes municipalities in the region, and the entire South for that matter, to be less prepared to respond to a large snowfall event (Bryant, 1991; Suckling 1991). Such an inefficient response can cause an increase in the cost of snowfall hazard mitigation efforts. Thus, if a heavy

snowfall occurs in the winter following a hurricane landfall, municipalities are faced with the problem of responding to not only a costly hurricane hazard response, but also a costly snow response. This cumulative response can cause both financial and organizational stress on emergency management agencies (Alexander, 1993).

It is difficult for government agencies to plan for such of a cumulative hazard because little, if any, research has investigated the occurrence of record snowfalls in a winter following a record hurricane rainfall. Therefore, no basic climate data, including frequency and magnitude of such occurrences, is available for agencies to make plans for response to heavy snows following hurricanes. Accordingly, the purpose of this paper is to create a baseline-climatology for the occurrence of record hurricane seasons followed by record snow seasons in eastern North Carolina. Specifically, this purpose will be supported by determining the frequency and probability of record hurricane-snow seasons in eastern North Carolina 1948-1999, the locations in eastern North Carolina where record hurricane-snow seasons are most likely to occur 1948-1999, the comparative magnitude of record hurricane-snow seasons in eastern North Carolina 1948-1999, and an explanation of why record hurricane-snow seasons occur. Information provided by this study may prove helpful to hazard mitigation activities of emergency management agencies, transportation agencies, and insurance companies. In particular, the characterization of hurricane-snow hazards may allow for agencies and companies to prepare and budget for extended hazard response from July through the following March.

Methodology

Analysis for this study was completed in a total of six steps. The first step was the identification of hurricanes that have made landfall in eastern North Carolina coast. Eastern North Carolina for this part of the study was defined as the portion of the state east of Charlotte. This area approximates the North Carolina coastal plain, the area closest to the coast and most likely to experience a land falling hurricane, and portions of the Piedmont. Portions of the Piedmont were included in the study to allow for the

identification of tropical systems that approach the Coastal Plain from the south or west and produce record rainfall. Tropical systems identified and included in this study were any Tropical Depressions, Tropical Storms, or Hurricanes with a path that entered North Carolina east of Charlotte. The systems were identified from the hurricane track archives produced by the National Hurricane Center as available through the Internet (<http://www.nhc.noaa.gov>).

The second step of analysis was the identification of daily rainfall records in eastern North Carolina associated with these landfall hurricanes. A record rainfall was defined in this study as the greatest rainfall on record at a specific weather station for a given date. The weather stations used in this study are all First Order National Weather Service stations located in the Coastal Plain or Eastern Piedmont, the region most similar to the Cfa climate type in North Carolina. A total of seven stations are used in the analysis, Cape Hatteras WSO, Elizabeth City FAA AIRP, Fayetteville, Greenville, Morehead City 2 WNW, Raleigh Durham WSFO AP, and Wilmington WSO Airport (Figure 1).

The National Climatic Data Center Summary of the Day, as compiled by Hydrosphere™, was used to identify rainfall records associated with tropical systems for the seven weather stations. The period of record used in this study was 1948-1999, except for Cape Hatteras, for which the period was 1957-1999. The rain records included in the study were records set during the time a tropical system's path was in eastern North Carolina.

The third step in analysis was the identification of daily snowfall records following a record rainfall from a landfall tropical system. The daily snowfall records used in this analysis were any daily snowfall record that occurred after a daily record from a tropical system but before the beginning of the next hurricane season. This time period included the fall, winter, and spring, all seasons in which snow has occurred in eastern North Carolina. The Hydrosphere database did not include record daily snowfalls for the year 2000. This data was required to identify snow after tropical system record rainfalls in 1999. So, daily records for January-May 2000 were downloaded from the National During the 52-year period of record, 25 years had at least one tropical system travel into eastern North During the

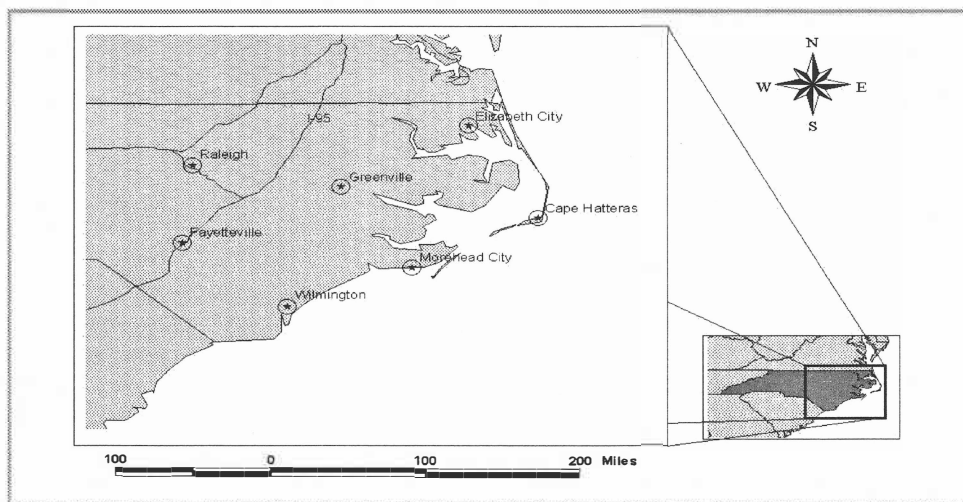


Figure 1. A map of eastern North Carolina displaying the location of weather stations used in analysis.

Climate Data Center's U.S. Daily Surface database available through the Internet (<http://www.ncdc.noaa.gov>), and used to identify daily record snowfalls.

Combination of daily record rainfall and snow data to identify record hurricane-snow seasons was the fourth step in analysis. If one of the weather stations in eastern North Carolina recorded both a daily record due to a tropical system and a record snow the following fall/winter/spring, the year of the tropical system was declared a record hurricane-snow season. Only one weather station with the record rain and snow occurrence was required for the classification but record hurricane-snow seasons can include record rain and snow at multiple weather stations and multiple record tropical systems or multiple record snow events. In fact, many years in the study period contain multiple record rain and snow events that cover multiple weather stations.

Once the record hurricane-snow seasons were identified, the fifth step in analysis, the determination of the location with the most frequent occurrence of record hurricane-snow seasons, was completed. Dividing the total number of record hurricane-snow seasons at a given weather station by the years in the period of record completed this step in the analysis.

The normalizing of the number of record hurricane-snow seasons by the period of record was required since all weather stations did not have the same period of record. Cape Hatteras's period of record was 1957-1999 as compared to 1948-1999 for the remaining weather stations.

The final step in the analysis was the assessment of the magnitude of record hurricane-snow seasons by determining the number of weather station that recorded record rain and snow during a record hurricane-snow season and ranking the amount of rain and snow recorded as records. By counting the number of weather stations observing record rain and snow, the relative size of a storm and the overall impact to eastern North Carolina as a whole can be inferred. A greater number of locations with a record indicates a larger area impacted by the storm. Assigning a numerical rank to the total amount of record rain and snow observed in a hurricane-snow season creates the second measure of magnitude. The total amount of rain and snow were divided by the number of stations receiving record rain and snow before assigning the numerical rankings. This division normalizes the data by area, and thus results are

not biased toward storms causing rain or snow over a large area. The two numerical ranks for rain and snow were then added together to provide an overall rank of magnitude for a record hurricane-snow season. Since the largest amounts of record rain or snow received a rank of 1, the lower the combined ranking the greater the magnitude of the record hurricane-snow.

Results and Discussion

52-year period of record, 25 years had at least one tropical system travel into eastern North Carolina (Table 1). This frequency can be expressed as a 0.48 probability of any year experiencing a tropical system in eastern North Carolina 1948-1999. Of the 25 years, 22 years had record rainfalls at at least one of the seven weather stations included in this study, a 0.88 probability. A total of 18 years between 1948 and 1999 recorded both a record rainfall created by a tropical system and a record snowfall the following fall, winter, or spring. Accordingly, the probability of a record snowfall after a record rainfall created by a tropical system in eastern

North Carolina 1948-1999 was 0.86. Thus, results indicate that once a tropical system causes a record daily rainfall it is highly likely that a record snow will follow in fall, winter, or spring. This is a somewhat surprising result given the description of the Cfa climate, a climate in which heavy snowfall is rare.

The eastern North Carolina locations that observed the most record hurricane-snow seasons for the given period were Raleigh and Wilmington (0.19 record hurricane-snow seasons per year), followed closely by Elizabeth City (0.17 record hurricane-snow seasons per year). Cape Hatteras followed these three stations with 0.11 record hurricane-snow seasons per year. The remaining three stations all had record hurricane-snow seasons per year below 0.10 (Figure 2). The reason for the stations with record hurricane-snow seasons per year above 0.10 is most likely that they are located in areas that either have the greatest annual tropical system frequency or snow frequency. Raleigh and Elizabeth City are located in the northern most portions of the study area, and Luthgens and

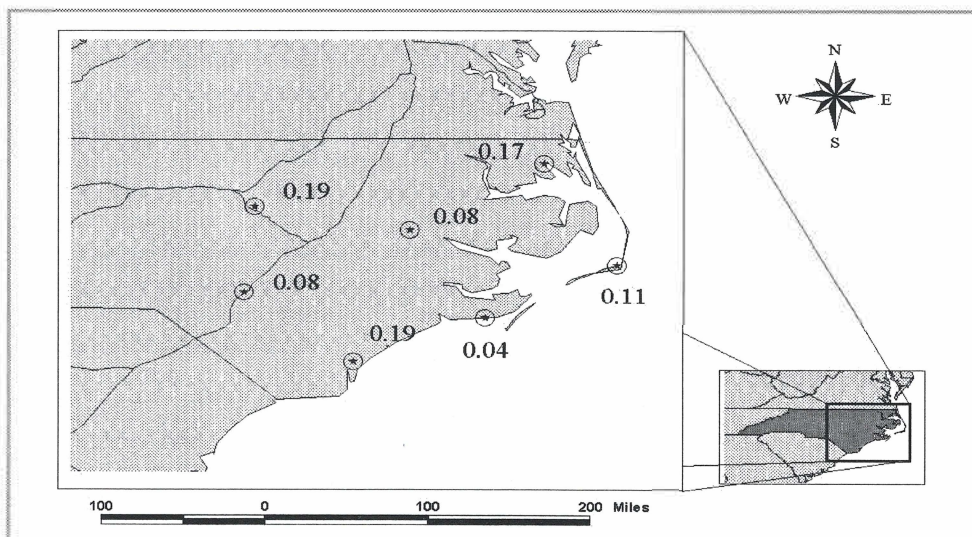


Figure 2. A map of the probability that a record rain-snowfall day will occur during any given hurricane-snow season in eastern North Carolina.

Table 1. Hurricanes making landfall in eastern North Carolina and the associated daily rain and snow records, 1948-1999.

Name	Start Date	End Date	Record Rainfall	Record Snowfall	Weather Station
Able	8/31/52	9/1/52	Y	N	Raleigh Durham WSFO AP
Barbara	8/13/53	8/14/53	Y	N	Elizabeth City FAA AIRP
			Y	Y	Greenville
			Y	N	Morehead City 2 WNW
Carol	8/30/54	8/31/54	Y	Y	Elizabeth City FAA AIRP
			Y	Y	Fayetteville
			Y	Y	Morehead City 2 WNW
Haze 1	10/15/54	10/16/54	Y	Y	Elizabeth City FAA AIRP
			Y	Y	Fayetteville
			Y	Y	Raleigh Durham WSFO AP
			Y	Y	Wilmington WSO Airport
Connie	8/12/55	8/13/55	Y	Y	Elizabeth City FAA AIRP
			Y	N	Greenville
			Y	N	Morehead City 2 WNW
			Y	N	Raleigh Durham WSFO AP
			Y	Y	Wilmington
Diane	8/17/55	8/18/55	Y	Y	Elizabeth City FAA AIRP
			Y	N	Greenville
			Y	Y	Raleigh Durham WSFO AP
Ione	9/19/55	9/20/55	Y	Y	Elizabeth City FAA AIRP
			Y	N	Greenville
			Y	N	Morehead City 2 WNW
			Y	Y	Wilmington WSO Airport
Flossy	9/26/56	9/28/56	Y	N	Fayetteville
			Y	N	Raleigh Durham WSFO AP

Name	Start Date	End Date	Record Rainfall	Record Snowfall	Weather Station
Brenda	7/29/60	7/30/60	Y	Y	Elizabeth City FAA AIRP
			Y	Y	Fayetteville
			Y	N	Greenville
			Y	Y	Raleigh Durham WSFO AP
			Y	Y	Wilmington WSO AIRP
Donna	9/11/60	9/12/60	Y	Y	Elizabeth City FAA AIRP
			Y	Y	Fayetteville
			Y	N	Greenville
			Y	N	Morehead City 2 WNW
			Y	Y	Raleigh Durham WSFO AP
Not Named	9/14/61	9/15/61	Y	Y	Wilmington WSO Airport
Alma	8/28/62	8/29/62	Y	Y	Cape Hatteras WSO
Cleo	8/31/64	9/3/64	Y	Y	Elizabeth City FAA AIRP
Dora	9/13/64	9/14/64	Y	Y	Elizabeth City FAA AIRP
			Y	Y	Fayetteville
			Y	Y	Greenville
			Y	Y	Raleigh Durham WSFO AP
			Y	Y	Elizabeth City FAA AIRP
Isbell	10/16/64	10/17/64	Y	Y	Elizabeth City FAA AIRP
			Y	Y	Raleigh Durham WSFO AP
Not Named	6/16/65	6/17/65	Y	Y	Cape Hatteras WSO
			Y	Y	Elizabeth City FAA AIRP
			Y	N	Fayetteville
			Y	N	Greenville
			Y	Y	Morehead City 2 WNW
			Y	Y	Raleigh Durham WSFO AP
Doria	9/16/67	9/17/67	N	n/a	All Stations
Abby	6/9/68	6/13/68	N	n/a	All Stations

Name	Start Date	End Date	Record Rainfall	Record Snowfall	Weather Station
Alma	5/26/70	5/27/70	N	n/a	All Stations
Not Named	8/17/70	8/18/70	Y	Y	Wilimington WSO Airport
Doria	8/27/71	8/28/71	Y	Y	Elizabeth City FAA AIRP
			Y	N	Morehead City 2 WNW
			Y	Y	Raleigh Durham WSFO AP
Agnes	6/21/72	6/22/72	N	n/a	All Stations
Bob	7/14/79	7/15/79	N	n/a	All Stations
David	9/5/79	9/6/79	Y	Y	Cape Hatteras WSO
			Y	Y	Elizabeth City FAA AIRP
			Y	Y	Fayetteville
			Y	Y	Wilmington WSO Airport
Dennis	8/20/81	8/21/81	Y	N	Cape Hatteras WSO
			Y	N	Elizabeth City FAA AIRP
			Y	N	Greenville
			Y	N	Morehead City 2 WNW
			Y	N	Wilmington WSO Airport
Diana	9/12/84	9/15/84	Y	Y	Cape Hatteras WSO
			Y	N	Fayetteville
			Y	N	Morehead City 2 WNW
Bob	7/25/85	7/26/85	N	n/a	All Stations
Danny	8/18/85	8/19/85	Y	Y	Cape Hatteras WSO
Gloria	9/26/85	9/27/85	Y	N	Greenville
			Y	N	Morehead City 2 WNW
			Y	N	Raleigh Durham WSFO AP
Kate	11/22/85	11/23/85	Y	Y	Raleigh Durham WSFP AP
			Y	N	Wilmington WSO Airport
			Y	N	Wilmington WSO Airport
Charley	8/17/86	8/18/86	Y	N	Morehead City 2 WNW

Name	Start Date	End Date	Record Rainfall	Record Snowfall	Weather Station
Allison	6/5/95	6/7/95	Y	N	Cape Hatteras WSO
			Y	N	Fayetteville
			Y	Y	Greenville
			Y	N	Morehead City 2 WNW
			Y	Y	Wilmington WSO Airport
Athur	6/19/96	6/21/96	Y	N	Cape Hatteras WSO
Bertha	7/12/96	7/13/96	Y	N	Greenville
			Y	Y	Wilmington WSO Airport
Fran	9/5/96	9/6/96	Y	N	Fayetteville
			Y	N	Morehead City 2 WNW
			Y	Y	Raleigh Durham WSFO AP
			Y	Y	Wilmington WSO Airport
Josephine	10/8/96	10/9/96	Y	N	Fayetteville
			Y	N	Greenville
			Y	Y	Raleigh Durham WSFO AP
			Y	Y	Wilmington WSO Airport
Danny	7/23/97	7/25/97	Y	N	Fayetteville
			Y	Y	Raleigh Durham WSFO AP
Bonnie	8/27/98	8/28/98	Y	Y	Wilmington WSO Airport
Earl	9/3/98	9/5/98	Y	N	Cape Hatteras WSO
			Y	N	Greenville
			Y	Y	Wilmington WSO Airport
Dennis	9/4/99	9/6/99	Y	Y	Elizabeth City FAA AIRP
			Y	N	Greenville
			Y	Y	Raleigh Durham WSFO AP
Floyd	9/16/99	9/16/99	Y	N	Greenville
			Y	Y	Raleigh Durham WSFO AP
			Y	Y	Wilmington WSO Airport

Table 2. The number of weather stations observing record rainfall and record snow fall by hurricane-snow season in eastern North Carolina.

Hurricane-Snow Season	Number of Weather Stations	Number of Weather Stations Divided by Number of Storms
1954	7	3.5
1960	7	3.5
1964	7	2.3
1955	6	2.0
1996	5	2.5
1965	4	4.0
1979	4	4.0
1997	4	3.0
1999	4	4.0
1971	2	2.0
1985	2	2.0
1995	2	2.0
1998	2	1.0
1953	1	1.0
1961	1	1.0
1962	1	1.0
1970	1	1.0
1984	1	1.0

Tarback (2001) note snowfall is most frequent in the higher latitudes of Cfa regions. Wilmington is located on the coast in the southeast portion of the state and Cape Hatteras is on the Outer Banks barrier island complex. It has been well documented that both of these locations frequently experience land falling tropical systems (Barnes, 1995, Hidore and Patton, 1996). Given the higher frequency of tropical systems and snow occurrence at these locations there is a greater possibility that these locations will experience both record tropical system rain or record snowfall.

The assessment of hurricane-snow season magnitude indicates that the number of tropical systems in a given year can cause difficulty in determining the area impacted during a hurricane-

snow season (Table 2). The years with the top three number of stations (7, 6, and 5) observing record rain and snow were all years with multiple storms, 1954, 1960, 1964, 1955, and 1996. These numbers don't truly represent the largest area affected in hurricane-snow season because the same weather station can have a record in multiple storms. However, dividing this total number of stations with record rain and snow in a hurricane season by the number of tropical systems, a more accurate measurement of the area impacted by a hurricane-snow season was presented (Table 2). After this division, 1965 and 1979 were the years with the largest area covered by record rain and snow with 4 weather stations followed closely by 1954 and 1960 with 3.5 stations. Combining this with the

Table 3. The ranking of the amount of rain and snow recorded on record days during record hurricane-snow seasons in eastern North Carolina.

Season	Total Rain (in)	Rain Rank	Rain Stations	Number of Stations	Total Snow (in)	Snow/ Station	Snow Rank	Overall Rank
1999	31.74	2	7.9	4	59.81	14.95	2	4
1979	20.34	4	5.0	4	67.61	16.90	1	5
1962	10.38	1	10.3	1	1.30	1.30	9	10
1964	18.46	11	2.6	7	39.85	5.69	3	14
1998	11.89	3	5.9	2	0.02	0.01	13	16
1954	17.57	12	2.5	7	27.15	3.87	5	17
1971	5.56	10	2.7	2	5.52	2.76	8	18
1965	9.09	13	2.2	4	14.62	3.65	6	19
1960	21.64	9	3.1	7	8.63	1.23	10	19
1995	6.70	8	3.3	2	2.01	1.00	11	19
1955	21.67	7	3.6	6	3.82	0.63	12	19
1996	20.66	5	4.1	5	0.05	0.01	14	19
1970	1.77	16	1.7	1	4.01	4.01	4	20
1961	1.37	17	1.3	1	3.10	3.10	7	24
1997	11.89	6	3.9	3	0.02	0.01	18	24
1953	1.84	14	1.8	1	0.01	0.01	15	29
1985	3.60	15	1.8	2	0.02	0.01	16	31
1984	1.3	18	1.3	1	0.01	0.01	17	35

rank of record rain and snow magnitudes, it is clear that 1979 was the worst hurricane-snow season, or the season with the largest area impacted with the most amount of rain and snow (Table 3).

Conclusions

Results indicate that a record snowfall occurring in the fall, winter, and spring after a record tropical

system has a relatively high probability or is relatively common in eastern North Carolina. This result is somewhat surprising taking into consideration the general characteristics of the Cfa climate type, hot summers and mild winters with little snow. So, the question remains, what causes record snow to be so common after record tropical system rainfall in eastern North Carolina? The authors believe that the high

probability of record rain and snow is not created by a physical process, but is a fallacy created by the database structure.

The first reason for believing the high probability was produced by the database structure is that there is no clear physical link between hurricanes and snowfall in the following fall, winter, and spring. A literature review by the authors produced no textbooks, articles, or other professional publications linking tropical system activity to snowfall the following fall/winter/spring. This absence of hypotheses as to the link led to a closer examination of the database and methodology used in the study.

This examination led to the realization that the utility of this analysis is related to the length of record used to determine daily rain or snow records. For this study, 52 years is the longest period of record for rain and snow. Thus the probability of a given year to experience a record rain or snow for a given date is 1 out of 52 or 0.02. Using a conservative definition of the hurricane season as July through October, there are 143 days in the hurricane season. Applying the binomial distribution, the probability of one or more days during this 143-day period to record a record rainfall (with a 0.02 probability) is 0.94, very high. Using a conservative definition of the snow season in eastern North Carolina (November through March) and applying the binomial distribution again, the probability of one or more days during the 153-day period to record a record is 0.95, even higher. Calculation of the conditional probability of a record snowfall occurring only if a record rainfall from a tropical system has occurred earlier produces a 0.95 probability. Therefore, based upon the length of record and fundamental laws of probability, a record rain and snow will most likely occur in eastern North Carolina regardless of physical process.

The high probability of record rain and snow in eastern North Carolina due to a short length of record is similar to difficulties in evaluating the 100-yr flood with annual peak flow series (Dunn and Leopold, 1978). The use of a short series of annual peak floods can cause the recurrence interval to be inflated and estimates of a 100-year flood to be unreliable. In fact, Lecce (2001) points out that the characterization of floods created by Hurricane Flood as a 500 yr flood are

inappropriate based upon the relatively short record of annual peak flood series.

The question now remains: since only 50 or so years of data exist, how can agencies accurately assess the risk of a cumulative hurricane and snow hazard? The answer is that it will be difficult. One thing is for sure, that snow and hurricanes in eastern North Carolina, a Cfa region, are not as rare as previously thought. In the last fifty years it has happened at least 18 times and preparation for a cumulative stress to emergency response organization may be worthwhile.

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Paying for the New Economy: The Geography of Equity Finance in North Carolina

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The availability of corporate finance is of critical importance to local and regional development. As firms increasingly substitute intangible assets (such as human capital, innovative capacity and brand equity) for tangible assets (factories, machinery and inventories), they are less able to collateralize the traditional source of capital, debt financing. Since equity finance (the offering of ownership shares through public stock markets) is the only method of capital acquisition that is not collateralized, the firms that compete most effectively for it are thought to be stronger competitors in the current marketplace. It was found that equity investment in North Carolina is highly concentrated both spatially (40% in Charlotte) and sectorally (56% in FIRE). Relatively small shares of equity are held by firms in the manufacturing (10% of the state total) and technology industries (9% of the state total). While the total amount of equity investment in North Carolina firms has increased, its increased concentration suggests a lack of diversity in the state's economy.

How much are 1.8 billion doughnuts worth? Investors in Winston-Salem based Krispy Kreme believe the company that makes them is worth \$1.6 billion dollars, or 88 cents per doughnut. These same doughnuts retail for less than 50 cents in stores. The response of investors to Krispy Kreme's recent success has allowed the company to expand aggressively outside of the Southeastern market it has served since 1937. After earning \$220 million in revenue in fiscal 1999, the firm offered 18% of the company to investors in an initial public offering (IPO) to raise the capital necessary to finance its expansion. This sale of stock (equity) raised over \$70 million and gave the firm a market value (the cost of purchasing 100% of the company) of \$389 million in April, 2000. The cash raised in the IPO enabled Krispy Kreme to finance its expansion into the Northeast and California markets and, by October, 2001, had increased its revenue by 56%. Investors favorably responded to the company's successful expansion and bid up the price of the company's shares by 411%, giving the doughnut producer a market value of \$1.6 billion. The company's primary asset, a brand image based on a doughnut recipe, is difficult to use as the collateral necessary for debt financing, so the public stock markets were the only source of capital of this magnitude available to finance Krispy Kreme's expansion. Public

equity markets can and do play a critical role in the expansion of corporations and, by extension, the health of the economies which are the home of these corporations. This paper is intended to explore the distribution of public equity finance in North Carolina and examine its relationship to economic growth in the state.

Public equity finance refers to the acquisition of capital via the sale of corporate ownership (shares) through a stock market. Public equity finance is the only means of corporate finance in which a company can securitize (borrow against future income) the value of intangible assets such as human capital (or in the case of Krispy Kreme, a doughnut recipe). Despite the increasing frequency with which corporations turn to equity markets for financing, the relationship between regional economic development and local corporate participation in equity markets has yet to be examined. While the availability of corporate finance is a critical factor in local and regional development, geographers have focused only on foreign direct investment (Campbell and Stuart 1998) or bank finance (Wheeler and Dillion 1985) as sources of capital for regional growth. Other studies have examined the local economic impacts of investment institutions (such as stock markets) or actors (such as brokers) (Warf and Cox 2000) but no studies exist that exam-

ine the connections between equity investment and local economic health. This gap in the geographic literature is of growing significance. As firms expand to serve global markets, increase the flexibility of their production system and rely on human capital to a greater degree than ever before, public equity markets have become the primary source of corporate finance, particularly for firms with few tangible assets.

The primary purpose of this paper is to evaluate the importance of equity finance to the North Carolina economy. A secondary purpose is to explain the spatial and sectoral distribution of equity finance within the state. This research is based on the assumption that the ability of North Carolina headquartered firms to attract corporate capital from public equity markets will be related to the health of the economy in which these firms are headquartered. It is hoped that a clear understanding of these patterns will provide insight into the future of the state's economy. To these ends, the paper first seeks to define equity investment, discuss the connections between equity markets and regional economies, and finally, to assess the importance of equity finance to North Carolina and its implications for economic development.

Public Equity Investment

The initial sale of ownership shares to investors (known as an initial public offering or IPO) via one of the major securities exchanges (such as the New York Stock Exchange or the NASDAQ) results in an immediate infusion of cash into a company. Stock trading that occurs after the IPO, known as the secondary market, does not directly benefit a company's finances, however, these transactions increase the liquidity of a company's shares and provide a valuation mechanism for the firm. This post-IPO market value is indicative of the willingness of investors to provide additional capital to these firms (Tobin 1969, Hatsopoulos 1999, Mangalindan 2000). High market values, in relation to the tangible worth of the firm, encourage companies to use their stocks as currency in acquiring the assets of other companies and facilitate secondary offerings of equity via securities markets to accrue additional cash (Madura 1992, Mishkin 1998). Krispy Kreme took advantage of its soaring market value to offer 9.2 million additional shares to the market in

March 2001 resulting in the flow of \$92 million of investment into the company's coffers. Low share prices not only discourage additional sales of stock but also make companies attractive takeover targets (Logue 1990, Donlan 2000, Wysocki 2000). This relationship between market value and the cost of capital has clear spatial implications. Cities that are the home to firms with high market values are more likely to benefit from corporate expansion, while the homes of low market value firms are more likely to be impacted by layoffs, corporate acquisition or disinvestment. Changes in equity capital flows have been correlated to employment changes in regional economies (Minns 1982, Coakley and Harris 1983, Botts and Patterson 1987). Even North Carolina's most prominent firms have experienced restructuring as a result of declining share price. The decline in market value associated with First Union's bungled acquisition of Core States Financial, for example, has been connected to layoffs within the Charlotte bank (Veverka 2000, Moyer 2000).

In most cases the benefits of public equity market participation outweigh the risks of shared ownership. In addition to increasing the availability of capital, other benefits, such as an institutionalized system of corporate governance, may add to the stability of the firm. Andr Boisvert, president and chief operating officer of SAS, the largest software company in North Carolina, states that SAS's upcoming IPO is primarily motivated by the need to provide its workers with an ownership interest in the company by providing them with liquid stock options (Rothacker 2001). Public companies that offer employees stock options may have a competitive advantage over firms that don't since employee options may reduce the total cost of employee compensation, provide management incentive to innovate and workers motivation to re-skill (although most options are held at the management level) (Friedman 1999).

Venture capital investment is frequently a precursor of a firm entering a public equity market. Venture capitalists take equity stakes in privately owned (pre-IPO) firms with the ultimate goal of profiting by selling these shares at the IPO. Since venture capital investment will typically lead public equity investment, its presence may indicate future growth of the num-

ber of equity financed firms (Leinbach and Amrhein 1987). North Carolina has never been a significant beneficiary of venture capital investment, according to PricewaterhouseCoopers *Money Tree Survey*; the state received only 1% of total venture capital invested in the U.S. during the first quarter of 2001. This contrasts sharply to the Silicon Valley area which received 30% of the venture capital invested during this same period. The relative absence of venture capital in the state is attributed to information asymmetries which reduce the willingness of venture capitalists to invest in spatially distant firms (Petzinger 1999). The scarcity of venture capital in North Carolina places the state at a disadvantage, relative to other states, for acquiring public equity investment. What little venture capital is invested in North Carolina is concentrated in non-technology firms suggesting that future investment may be concentrated in slow growth areas of the economy such as manufacturing (Lundegaard 1999). Spatial biases in venture investment are dramatic within the state as well. Table 1 shows that the majority of venture capital investment flows to the Triangle area

– the most likely growth location for equity financed firms.

Equity Investment and Regional Economic Development

This study follows a strong tradition of corporate headquarters research. The presence of corporate headquarters has long been used as a measure of command and control status based on the assumption that these are the sites of decision-making and profit accumulation in the modern economy. It is thought that this command and control status gives places a greater degree of control over their economic destinies in addition to being the primary beneficiaries of corporate profit growth (Pred 1977, Borchert 1978, Semple, Greene and Martz 1985, Noyelle and Stanback 1983, Wheeler 1987). This study seeks to improve upon the traditional approach by using the market value of a firm to measure not only its relative importance, but also its potential for growth. For example, Krispy Kreme has maintained its corporate headquarters in Winston-Salem since 1937 but its contributions to the local economy are poised to increase considerably after acquiring more than \$100 million from equity investors. This expansion potential would have gone unnoticed in a traditional corporate headquarters study.

The difficulty associated with corporate headquarters research is the prominence of multi-location firms. Regardless of the spatial distribution of large corporations, the profits generated by the firm will ultimately flow back to the headquarters site (Holloway and Wheeler 1991). In addition, it has been shown that the headquarters location is the site of most of the research and development (Ceh 1997, OhUllachain 1999), and expenditures on high-order services (Mitchelson and Wheeler 1994). The presence of corporate headquarters has been shown to create additional employment, as well as stimulate the demand for office space (Noyelle and Stanback 1983, Wheeler 1987, Lord 1992). In addition, the provision of local grants and charitable gifts to the surrounding community is thought to be related to headquarters location (Martin 1999). While critics consider corporate headquarters research to be an oversimplification of

Table 1. Venture capital investment in North Carolina large metros, 1999 (as % of GMP)

MSA	Venture Capital	MSA Rank
Raleigh-Durham	1.35%	5
Charlotte	0.10%	33
Greensboro-Winston Salem	0.00%	50

Source: Atkinson and Gottlieb (2001)

economic processes, the importance of command and control status to a community is certainly relevant to a local economy and therefore worthy of analysis. The fundamental contention of this paper is that a firm's command and control status is proportional to its market value.

In the early stages of industrialization of the U.S. South, corporations were typically financed informally through personal relationships. The large scale commercialization of corporate finance in the South didn't begin until the early 1900s when banks formalized the process of attracting excess capital and redistributing it to the rapidly expanding textile industry via loans secured on the basis of collateral such as factories or equipment (Hanchett 1998). As industrial production expanded into national markets, often by establishing multiple production sites and the substitution of capital for labor, the corporate demand for capital began to outstrip the ability of banks to provide it (Miller 1998). The modern production systems, which rely on constant innovation and the associated human capital, have dramatically increased the corporate demand for capital just as firms are becoming leaner and have less collateral to back borrowing (Nakamura 1999, Epstein 2000). The twin conditions of increased capital needs to fund the acquisition of intangible assets, such as research and development, and the decline of tangible assets used for collateral has made it critical for modern companies to find alternative methods of corporate finance. Public equity markets have become known as the only method of securitizing the growing value of intangible assets held by modern firms, and thus the only way to leverage these assets (The Economist 2001). Hence the regional economies that are the home of the most flexible or innovative firms are likely to have the highest levels of public equity investment.

When equity investments involve an exchange of cash between companies and investors that are spatially distant, securities markets act as capital relocation mechanisms. The interregional flow of capital has been accelerated by the rapid globalization of the financial industry and the desire of investors to geographically diversify their portfolios. The multinational nature of stock markets provides firms offering shares access to a global pool of capital. However, since the

total amount of capital is fixed, companies must compete for this capital. The migration of capital that results from this competition may act to drain capital from the least productive regions, a process that Myrdal (1957) referred to as a "backwash" effect of development. There are numerous exceptions to Myrdal's assertion that capital will flow to the most productive users. Information asymmetries may encourage capital to flow towards the best-known or largest companies since a relatively larger amount of information is available to investors on these firms (Yang, Wansley and Lane 1985). This disproportionate flow of equity capital to the largest companies may make it increasingly difficult for small firms to obtain equity capital, a problem for the majority of public equity firms in North Carolina. Market frenzies or sectoral bubbles may also skew the inter-regional distribution of capital. The dot com market frenzy of the late 1990s, funneled huge amounts of investment capital to companies with few tangible assets and no profits. The promise of massive (and as yet unfulfilled) profits attracted billions of dollars of speculative equity investment which would have been unobtainable from any other source given the lack of collateral or established business models. This market bubble produced numerous economic impacts in the Silicon Valley area, including high rates of employment growth, entrepreneurship, and increased real estate prices (Grimes 2000).¹

Many policy makers have questioned the reliability and sustainability of equity investment as a means of financing long-run development. However, other research suggests the perceived fickleness of equity investment seems to have little empirical basis (Stulz 1999, Claessens, Dooley, and Warner 1993). These studies suggest that the risk reduction associated with diversification of ownership and the decreased cost of capital appears to mitigate the problems associated with the mobility of equity investment. It may, however, be difficult to make this argument at the scale of the individual firm when declining share prices are frequently cited as causes of corporate downsizing.

There are situations where increased market values may have no significant local impact. Firms may not have the opportunity or desire to take advantage of short-term increases in market value to make addi-

tional investments or acquisitions. The problem of short-term skewing can be reduced analytically by temporally averaging market values over one year (or longer) periods, relying on aggregate data and comparing relative (rather than absolute) volumes of investment. In other situations, firms may utilize their increased market value to expand outside of their headquarters site, in this case there may be no direct benefits to the local economy beyond increases in command and control status and profit accumulation. The volatile nature of public equity investment makes its direct impacts difficult to quantify, however, these flows are likely to provide substantial, if sometimes temporary, benefits to the local economy.

Data and Method

Stock price data are one of the most current sources of economic information; the data used here were taken from the *Global Access Database* (Primark Corporation 2001). Data were collected for January 1990 and January 2001. These share prices, which are used to calculate the market values of firms, are based on audited financial data that is reported to the U.S. Securities and Exchange Commission (SEC) annually. These data were collected during an exceptional period for the investment community. The dramatic appreciation of technology stocks resulted in massive shifts of investment towards these production complexes. While these shifts were substantial in absolute terms, the relative differences in inter-regional investment have remained steady since the 1980s (Graves 2000). The market values used here are based on the closing price of each company on the last business day of January of each year. Companies that do not have at least 500 shareholders and \$5 million in assets are excluded from the database. In addition, companies that do not provide goods or services directly to a consumer or other business – including management investment companies, mutual funds, real estate investment trusts, limited partnerships and oil and gas drilling funds – are also omitted from the database.

These data are geocoded according to the county that is the home of the firm's headquarters office. This technique has the advantage of being simple and consistent and is compatible with previous corporate headquarters studies. As discussed earlier, there are a

sufficient number of firms that are spatially disaggregated (notably the banks and retailers) to make the assumption of spatially aggregated firms problematic. However, with the exception of North Carolina's 15 largest firms, most companies in this data set centralize their operations within the headquarters' county.

This exploratory analysis of equity investment data will be accomplished using two descriptive statistics. First, the state's participation in equity markets relative to population will be measured by comparing the state's share of U.S. equity investment to its share of the nation's population using a location quotient. The location quotient is calculated as follows:

$$LQ_{\text{equity}} = (\text{State Market Value} / \text{U.S. Market Value}) / (\text{State Pop} / \text{U.S. Pop})$$

Location quotient values less than one indicate that the state has less equity investment per person than the national average. Conversely, location quotient values greater than one indicate states with higher concentrations of equity investment than the national average. Second, the intra-state concentration of this equity investment is measured using a Gini coefficient. The Gini coefficient measures the percent departure from a uniform distribution and its value ranges from zero (even distribution) to one (concentrated distribution). The Gini coefficient is calculated as:

$$G = 0.5 \sum |Q_i - Y_i|$$

where Q_i is the percent of market value in the i -th firm and Y_i is the expected percent if the distribution is uniform. States with only one publicly-traded firm will have Gini values of one while states with their equity investment evenly distributed between more than one firm will have Gini values of zero.

Equity Investment in North Carolina

North Carolina firms are well established in U.S. equity markets. The state is home to 123 publicly owned companies employing more than 800,000 workers nationwide and generating sales of over \$200 billion during fiscal 2000 (Primark Corporation 2001). In aggregate, these companies are worth nearly \$240 billion, based on market values calculated from January 2001 data. While the amount of equity investment in North Carolina firms is substantial, it is concentrated in a relatively small number of industries and firms. Over half of the state's equity investment

(as measured by market value) is in the state's four largest banks which are headquartered in either Charlotte or Winston-Salem (Table 2).

Establishing the importance of public companies relative to privately owned firms is difficult due

to data limitations. However, limited estimates of the size of private firms are published annually. According to Speizer (2000) only 6 privately held firms in North Carolina have revenue greater than \$500 million in 1999, this compares to the 37 public compa-

Table 2. Largest public companies in North Carolina by market value. January 2001

Rank	Company	Headquarters City	Industry	Market Value (billions of dollars)
1	Bank of America	Charlotte	Banking	79.34
2	First Union	Charlotte	Banking	30.78
3	Duke Energy	Charlotte	Utility	30.26
4	Lowe's	North Wilkesboro	Retail	19.14
5	BB&T	Winston-Salem	Banking	15.02
6	Wachovia	Winston-Salem	Banking	13.39
7	Progress Energy	Raleigh	Utility	8.87
8	Jefferson Pilot	Greensboro	Insurance	6.98
9	RJ Reynolds Tobacco	Winston-Salem	Manufacturing	5.62
10	Laboratory Corp of America	Burlington	Medical Lab. Services	4.63
11	Family Dollar Stores	Charlotte	Retail	4.18
12	V F Corp	Greensboro	Textiles	4.00
13	B F Goodrich	Charlotte	Aerospace	3.77
14	Carolina Power & Light	Raleigh	Utility	3.64
15	Nucor	Charlotte	Steel	3.35
16	RF Micro Devices	Greensboro	Semiconductors	2.98
17	Quintiles Transnational	Durham	Contract Medical Research	2.59
18	Spectrasite Holdings	Cary	Telecommunications	2.36
19	Cree	Durham	Silicon Light Devices	2.22
20	Delhaize America	Salisbury	Retail	2.20
21	Centura Banks	Rocky Mount	Banking	2.18
22	Marin Marietta Materials	Raleigh	Mining	2.03
23	CCB Financial	Durham	Banking	1.51
24	Red Hat	Durham	Software	1.31
25	Pharmaceutical Product Dev.	Wilmington	Contract Medical Research	1.26

Source: *Global Access*

nies in the state which exceed this revenue figure in 1999. With the single exception of software producer SAS, the largest privately owned firms in the state are in the manufacturing and retail sectors of the economy. The state's publicly owned firms are dominated by the finance, utility or technology industries.

The total value of equity investment in companies headquartered in North Carolina has increased from \$19.6 billion in 1990 to \$239 billion in December of 2000.² The ratio of equity investment to Gross State Product in North Carolina increased from 12.4% to 91% of GSP during the same period. While these figures represent substantial investments they are well below the national norm of equity investment levels equal to 146% of gross state product. This increase in the volume of equity investment discussed above is not related to changes in the number of publicly financed companies in the state (123 companies in 2000 versus 103 companies in 1990); rather it appears to be a result of an increase in the valuation of existing equity firms. The increase in mean market value of North Carolina public firms shown in Table 3 parallels national trends.³

The values in Table 4 show the interstate distribution of equity investment. The states with the highest absolute levels of equity investment, California, New York and Texas have dramatically increased their volume of equity capital since 1990. This volatility does not appear to affect the lowest ranked states in terms of aggregate equity investment, Wyoming,

Alaska and Montana have maintained essentially static levels of investment since 1990. According to the location quotient data in Table 4, only 13 states have a greater national share of equity investment than population, suggesting that equity investment is strongly skewed towards these states, generally those in the urban core of the country. While North Carolina was not in the top tier of states in terms of the volume of investment, the state was one of only 14 to increase its proportion of equity, relative to population, since 1990. The slight increase in the state's share of capital suggests that North Carolina firms have, in aggregate, become more attractive to investors since 1990, suggesting that the state's firms have been successful in the global competition for capital.

The degree of inter-firm concentration of each state's equity investment is also shown in Table 4. Equity investment in North Carolina is more concentrated than the national average in both 1990 (0.66) and in 2000 (0.72). The change in Gini values since 1990 indicates that the majority of equity investment in the state has accumulated in the largest firms and resulted in less diversification in equity investment during the decade. This trend towards the consolidation of equity assets in a small number of companies is consistent with national trends; 40 of the 51 states experienced an increased concentration of assets during the study period. This concentration of equity investment may pose risks to state economies by limiting the diversity of equity investment. An economic

Table 3. Overview of public companies in North Carolina

Year	Firms	Total Market Value (billions)	Mean Market Value (billions)	Total Revenue (billions)
2000	123	\$ 239.1	\$ 2.20	\$ 201.0
1990	102	\$ 17.5	\$ 0.20	\$ 37.5

Source: *Global Access*

Table 4. Distribution and concentration of equity investment by state (sorted by LQ 2000).

State	Market Value 2000 (billion)	Market Value 1990 (billion)	LQ 2000	LQ 1990	Gini 2000	Gini 1990
CT	\$ 696.27	\$ 233.43	4.25	4.31	0.83	0.77
DC	\$ 85.42	\$ 21.08	3.11	2.11	0.79	0.66
DE	\$ 105.13	\$ 49.47	2.79	4.51	0.83	0.67
WA	\$ 713.71	\$ 89.40	2.52	1.12	0.87	0.75
NJ	\$ 942.17	\$ 186.67	2.33	1.47	0.85	0.79
AR	\$ 297.32	\$ 72.11	2.31	1.86	0.92	0.77
NY	\$ 1,935.85	\$ 672.59	2.12	2.27	0.83	0.80
CA	\$ 2,636.05	\$ 420.27	1.62	0.86	0.78	0.73
GA	\$ 563.32	\$ 175.67	1.43	1.65	0.83	0.77
MA	\$ 397.65	\$ 102.57	1.30	1.04	0.69	0.65
TX	\$ 1,191.53	\$ 308.32	1.19	1.10	0.80	0.74
IL	\$ 708.73	\$ 305.24	1.19	1.62	0.74	0.67
VA	\$ 378.84	\$ 103.61	1.11	1.02	0.80	0.76
NE	\$ 73.08	\$ 13.34	0.89	0.51	0.70	0.61
MN	\$ 206.69	\$ 97.38	0.87	1.35	0.74	0.73
CO	\$ 164.16	\$ 57.00	0.79	1.05	0.79	0.79
OH	\$ 397.12	\$155.54	0.73	0.87	0.72	0.65
RI	\$ 32.92	\$ 12.44	0.65	0.75	0.78	0.69
MS	\$ 88.63	\$ 6.22	0.65	0.15	0.89	0.52
NC	\$ 236.44	\$ 62.30	0.61	0.57	0.78	0.70
ID	\$ 34.14	\$ 13.42	0.55	0.81	0.72	0.43
PA	\$ 322.30	\$ 214.17	0.55	1.10	0.70	0.72
MI	\$ 244.28	\$ 175.63	0.51	1.15	0.79	0.77
MO	\$ 133.74	\$ 105.79	0.50	1.26	0.69	0.72
IN	\$ 129.35	\$ 58.06	0.44	0.64	0.78	0.71
NM	\$ 35.60	\$ 2.01	0.41	0.08	0.91	0.63

State	Market Value 2000 (billion)	Market Value 1990 (billion)	LQ 2000	LQ 1990	Gini 2000	Gini 1990
UT	\$ 42.57	\$ 15.88	0.40	0.56	0.76	0.77
MD	\$ 93.75	\$ 21.56	0.37	0.27	0.67	0.63
OR	\$ 50.97	\$ 20.55	0.31	0.44	0.72	0.69
WI	\$ 79.06	\$ 32.26	0.31	0.40	0.63	0.54
OK	\$ 49.87	\$ 25.49	0.30	0.49	0.72	0.73
TN	\$ 78.55	\$ 34.72	0.29	0.43	0.66	0.62
FL	\$ 192.15	\$ 71.43	0.25	0.34	0.71	0.75
ME	\$ 14.50	\$ 5.80	0.24	0.29	0.69	0.68
IA	\$ 33.07	\$ 14.09	0.24	0.31	0.67	0.57
NH	\$ 13.91	\$ 11.57	0.23	0.63	0.60	0.71
NV	\$ 22.02	\$ 15.61	0.23	0.79	0.69	0.65
AL	\$ 42.92	\$ 19.71	0.20	0.30	0.64	0.53
AZ	\$ 49.08	\$ 11.55	0.20	0.19	0.66	0.71
LA	\$ 31.99	\$ 27.32	0.15	0.39	0.68	0.66
KY	\$ 26.08	\$ 14.05	0.13	0.23	0.67	0.63
SC	\$ 22.23	\$ 10.57	0.12	0.18	0.69	0.59
VT	\$ 2.91	\$ 1.79	0.10	0.19	0.51	0.50
ND	\$ 3.02	\$ 0.71	0.10	0.07	0.54	0.59
HI	\$ 5.30	\$ 5.17	0.09	0.28	0.59	0.57
KS	\$ 10.80	\$ 13.47	0.08	0.33	0.62	0.74
SD	\$ 2.91	\$ 1.01	0.08	0.09	0.57	0.46
MT	\$ 2.86	\$ 1.84	0.07	0.14	0.68	0.67
WV	\$ 3.50	\$ 2.26	0.04	0.08	0.59	0.38
AK	\$ 1.33	\$ 0.71	0.01	0.08	0.42	0.35
WY	\$ 0.13	\$ 0.40	0.01	0.05	0.54	0.82
Ave.	\$ 267.17	\$ 80.26			0.72	0.66

Source: Calculated by authors from *Global Access*

misstep by one of these large firms may have a greater regional impact in terms of capital availability than in the past.

Figure 1 graphically displays the data shown in Table 4 – log-transformed location quotients are plotted on the X-axis and the Gini values are plotted on the Y-axis. The axes are oriented such that the origin represents a Location Quotient of 1.0 (log value of zero), reflecting the national average and a Gini value equal to the national mean of concentration (0.72). States on the right side of Figure 1 have attracted a disproportionate share of equity investment, suggesting that firms in these states are perceived to be more innovative or productive than other firms. States on the left side of Figure 1 have attracted the least equity investment per capita, suggesting that employment in these states is in predominantly subsidiary or branch

plant sites. States in the top half of Figure 1 have equity investment that has a greater inter-firm concentration than the national average – possibly indicating a lack of diversification of equity finance. States at the bottom of Figure 1 have equity that is more evenly distributed than the national average, possibly indicating less dependence upon a small number of firms for capital. Every state but Massachusetts that has a high relative amount of equity investment also has its equity investment concentrated in a relatively small number of companies. North Carolina's position in Figure 1 indicates that its equity landscape is similar to states such as Colorado, Michigan, Indiana, Rhode Island and Minnesota – states that have moderate levels of equity investment per person and high levels of equity concentration in their largest firms. The strong correlation between these two variables is in-

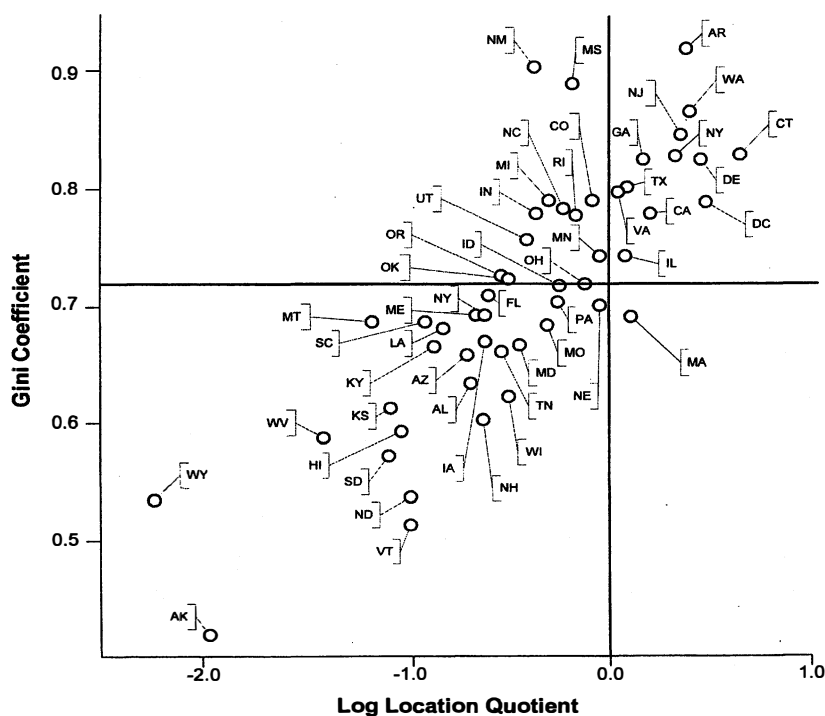


Figure 1. Location quotient and Gini Coefficient by state, 2000

dicative of the bias of public equity investment towards the largest firms driven by information asymmetries. The states that are least successful in attracting public equity investment appear to lack large, "lightening rod" firms that are the principle attractors of capital. While this concentration of investment in large firms appears to benefit states in terms of the aggregate amount of equity capital, it is at the expense of the diversity of these economies.

North Carolina Equity Investment by County

Figure 2 shows the location of North Carolina public firms by county. As expected, the greatest concentrations of public firms are found along the state's urban crescent: Mecklenburg County (26 firms), Wake County (23 firms), Durham County (11 firms) and Guilford County (11 firms). While a small number of public companies are scattered outside the urban core, Catawba and New Hanover counties are the only locations with three or more equity financed companies. However, several of the state's largest firms are headquartered outside of major urban areas; they include Lowes (Wilkes county, home improvement re-

tailer), Delhaize America (Rowan county, grocery retailer) and Centura Bank (Nash county).⁴ Since Figure 2 displays only the location of the state's public companies, a second evaluation of the size of these companies follows.

The distribution of equity investment dollars differs dramatically from the distribution of public companies (Figure 3). The dominance of the largest firms suggested by the Gini index value in Table 4 is also apparent from Figure 3. Five of the six largest recipients of equity investment in the state are in either Mecklenburg or Forsyth counties. The majority of this investment is in the four large banks (Bank of America, First Union, Wachovia, BB&T), Duke Energy (utility), and RJ Reynolds (tobacco product manufacturing). The sixth firm, Lowes, has stated its intention to move some of its corporate operations to the Charlotte metropolitan area during 2002. Comparison of Figures 2 and 3 reveals that the presence of a large number of firms in Wake county is mitigated by their small aggregate total market value.⁵

The substantial disparity in total market value between the Research Triangle and Charlotte areas

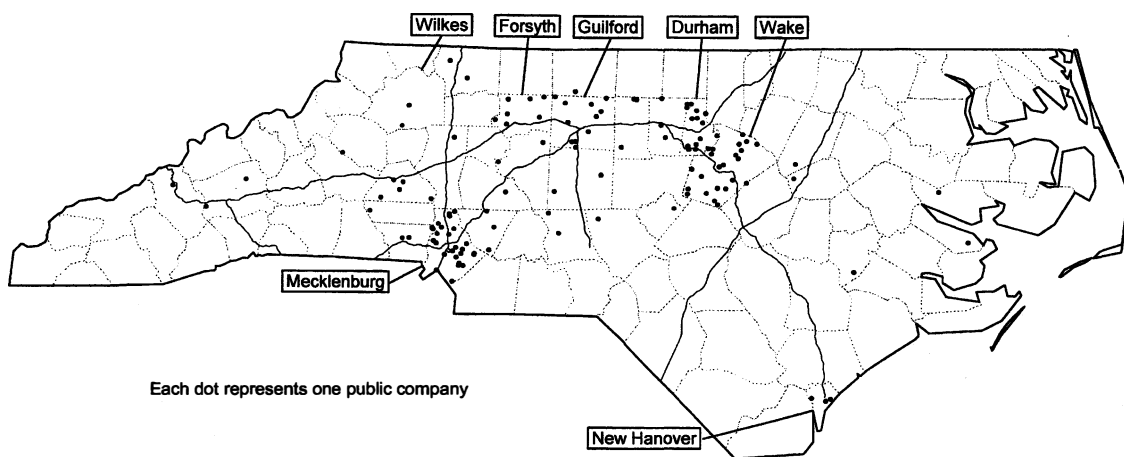


Figure 2. Public companies by county, 2001

shown in Figure 3 is surprising since both metropolitan areas have roughly equal amounts of total employment and numbers of public companies. However, the expansion of large amounts of non-government related employment in the Triangle has been a relatively recent phenomenon. The Triangle's public companies are generally younger than the public companies elsewhere in the state and have not been able to develop high degrees of visibility on Wall Street. In addition, there is anecdotal evidence to suggest that nascent technology firms in the Triangle have difficulty obtaining financing from distant venture investors (Lundegaard 2000). These data support this suggestion and illustrate the subsidiary nature of technology employment in the Triangle. Since the primary technology employers in the area (such as IBM, Cisco and Nortel) are headquartered outside North Carolina, profits generated by workers in this sector are exported to other states. This lack of command and control has not impeded the region's employment growth, but does make it dependent on decisions made outside the area. Recent layoffs in several Tri-

angle technology firms, including Nortel and Cisco Systems, are evidence of this risk.

Composition of Equity Investment in North Carolina

The state-level analysis of the distribution of equity capital in Table 4 revealed a high degree of concentration of North Carolina's equity investment in a small number of companies. Examination of the industries that have benefitted most from equity investment shows that imbalances exist at the industry level as well. Table 5 shows that the vast majority of the equity investment in North Carolina is in finance, insurance and real estate (FIRE) sector firms, particularly banks. While the importance of financial firms to the state economy is widely acknowledged, the extent of the industry's dominance, as measured by market value, is disproportionate to its employment share. In January 2001, 51% of the state's market value was composed of the state's four largest banks (Bank of America, First Union, BB&T, Wachovia)⁶ – an increase

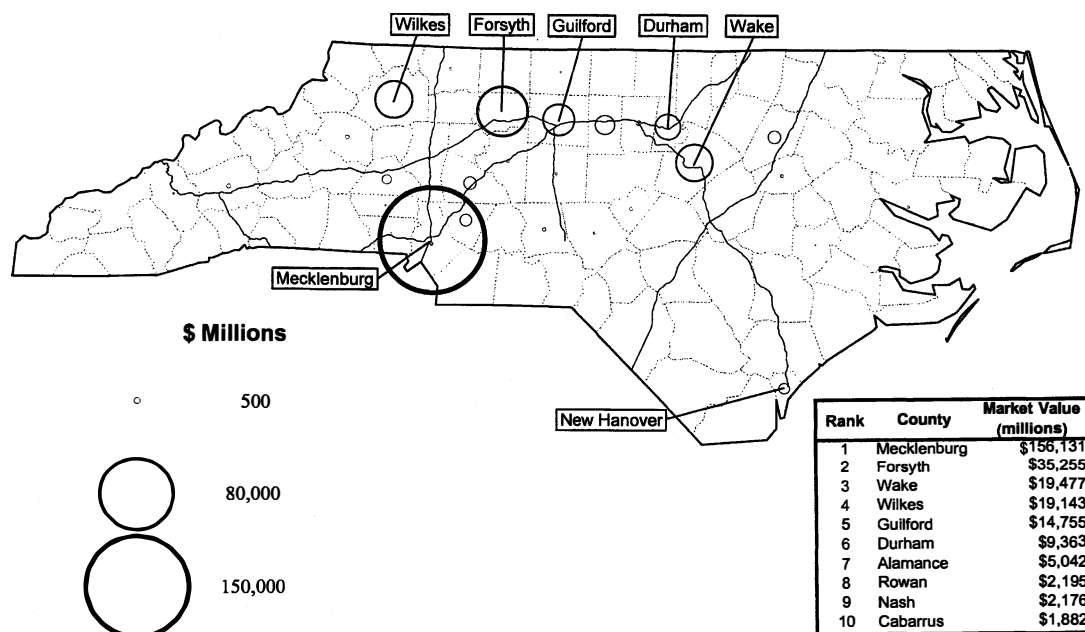


Figure 3. Aggregate market value by county, 2001

Table 5. North Carolina public companies by industry, January 2001

Industry	Firms 2000	Total MV (billions) 2000	% of State Total 2000	% of US Total 2000	Firms 1990	Total MV (billions) 1990	% of State Total 1990	% of US Total 1990
FIRE	30	\$ 152.65	56.55%	18.80%	36	\$ 9.78	48.87%	16.22%
Transportation and Utilities	11	\$ 46.96	17.40%	8.62%	11	\$ 6.27	31.36%	12.23%
Retail	10	\$ 28.16	10.43%	1.71%	9	\$ 1.41	7.05%	4.56%
Manufacturing	40	\$ 27.72	10.27%	28.78%	27	\$ 1.83	9.13%	47.71%
Services	25	\$ 12.27	4.55%	58.55%	1	\$ 0.04	0.21%	4.73%
Agriculture and Mining	1	\$ 2.03	0.75%	0.63%	1	\$ 0.01	0.04%	8.43%
Wholesale Trade	4	\$ 0.13	0.05%	1.56%	5	\$ 0.31	1.54%	4.01%
State Total	121	\$ 269.92	100.00%	1.98%	90	\$ 19.65	98.20%	0.87%
"Technology"* Sectors	43	\$ 26.25	9.72%	58.16%	7	\$ 0.16	0.79%	30.83%

*(Includes Instruments and Related Products, Electronic Equipment, Industrial Machinery, Chemicals, Communications, Business Services (including software), Health Services, Engineering and Management Services)

Source: Calculated by authors from *Global Access*

from 33% of the state's total equity in 1990. The 30 FIRE firms within the state comprise nearly 57% of the state's total market value. Utility firms (Duke Energy and Progress Energy) compose an additional 17% of the state's total market value. This sector experienced the greatest decline in importance since 1990. The FIRE and utility industries together make up nearly 75% of the state's total equity investment. In contrast, FIRE and utility companies make up only 27% of the nation's total market value. Retail and manufacturing firms receive the majority of the remaining investment within the state. The retail industry (dominated by Lowes, Family Dollar and Delhaize) accounts for just over 10% of the state's total public equity investment (the national average is

1.7%). The manufacturing sector, unlike the other major industries in the state, does not appear to be dominated by large firms, and despite the sector's dominance in terms of employment, these firms make up only 10% of the state's equity investment, well below the 28% national average. Relative to the remainder of the state's economy, investment in the manufacturing industry has remained essentially unchanged since 1990. While manufacturing is perceived to be important to the state's economy in terms of employment, it appears that the industry is largely controlled by companies headquartered outside of the state.

Table 5 also presents the aggregate data for the state's publically owned technology firms.⁷ These com-

panies account for only 9.72% of the state's total market value. While this level of investment pales in comparison to the proportion of national equity dollars in the technology industry (58%), this figure represents a substantial increase in the state's technology sector investment since 1990 and a greater growth rate than the nation as a whole. The gains in technology sector investment are promising but the relatively low level of investment in the sector is indicative of the subsidiary nature of the technology sector in the state. In addition, the lack of any large technology firms (i.e. market capitalization greater than \$5 billion) may handicap the state's firms in their competition for equity investment. The distribution of technology firms in the state shares the urban bias of public companies in general (Figure 4). While the Research Triangle area dominates the distribution of technology firms, Mecklenburg county (generally perceived as a financial center) also is the home to a significant number of these firms. The two technology clusters that are evident from Figure 4 are somewhat misleading since

two of the largest technology firms in the state are located in New Hanover (Pharmaceutical Product Development, \$1.26 billion) and Guilford (RF Micro Devices, \$2.98 billion) counties.

Finally, the size of companies in these counties may influence the future flow of capital. It was previously noted that information asymmetries make large capitalization companies attractive investments as securities markets continue to globalize and the distance between investor and investment increases. This situation is expected to skew investment towards large capitalization firms. However, only nine North Carolina stocks are large enough to be considered "large capitalization" firms by Wall Street's definition (market value greater than \$5 billion). Since seven of these nine firms are in either the FIRE or utility sectors, and seven of the nine are located in either Charlotte or the Triad area, the future flow of capital may be highly concentrated in these two areas and sharply reduced in periods of low interest rates (which generally reduce the profitability of FIRE firms). North Carolina's

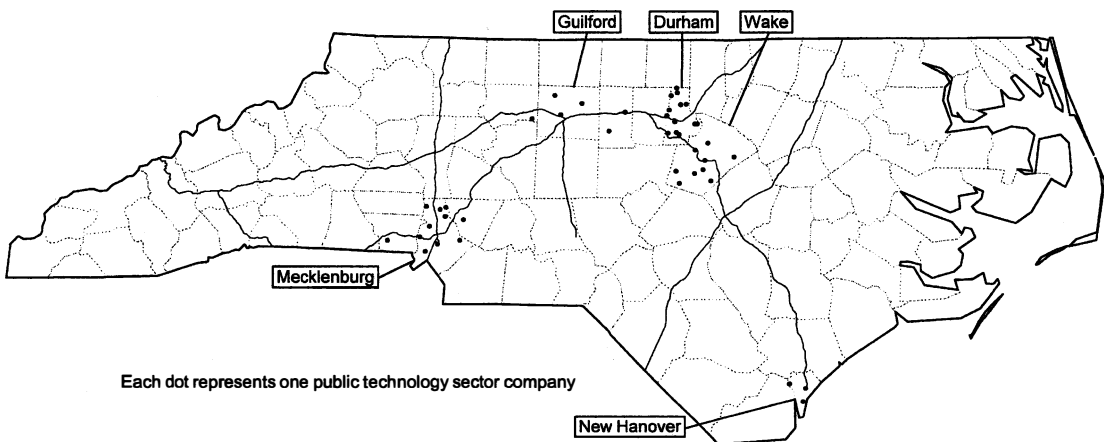


Figure 4. Public technology companies by county, 2001

sectoral dependence on FIRE firms may make it difficult to attract "hot money" from Wall Street.

Conclusions

Corporations' increased reliance on intangible assets such as human capital have heightened the importance of equity finance to corporate growth. Since the ability of a firm to obtain capital is critical to its ability to expand, linkages exist between the availability of public equity investment and the regional economies that house these companies. Firms with high market values are more likely to create spillovers in the local economy; these spillovers may include the increased demand for office space, local business services and employment growth. Taken in the aggregate, market values reflect investors' opinions of regional corporate productivity. In this sense, the aggregate market value of North Carolina-headquartered firms is indicative of the ability of the state's companies to compete for equity capital in a global economy. While absolute measures of equity investment are highly volatile and are dependant upon market psychology, relative differences in volumes of equity investment can be used to illustrate real or perceived differences in the productivity of public equity firms between cities or states. North Carolina has been moderately successful in attracting equity finance, \$270 billion in 2000, ranking the state 20th in the total amount of public equity capital investment per person. Despite the mediocre ranking, these data indicate an increase in investment, relative to other states, over the previous decade.

While the urban concentration of equity investment in North Carolina is no surprise, the sheer dominance of the banking industry and its headquarters sites in Mecklenburg and Forsyth counties is remarkable. The banking industry accounts for over 56% of the equity investment in the state, overwhelming all other industries, including the emerging technology sector. This "eggs in one basket" situation may increase the state's vulnerability to economic downturn. The low market values of firms in the manufacturing, service, and wholesale sectors of the economy relative to national norms suggest that these local firms are perceived to be less competitive in the global invest-

ment marketplace and that the state risks their loss through corporate acquisition and merger activity or closure. Investment in the state's technology firms, while low in an absolute sense, has grown dramatically in the 1990s, suggesting that the state's efforts in promoting the sector have been successful.

This paper does not intend to argue that public equity capital will flow to the most efficient users; it merely asserts that companies that are offered large amounts of capital by markets will benefit while companies which are less popular with public equity markets will languish and that this relationship will have a spatial manifestation. This paper is merely a first step in a much larger examination of the linkages between Wall Street and local economies. Additional research should include investigations into the relationship between aggregate market values and local employment, examinations of the negative local externalities of declining stock price, and firm level case studies seeking to evaluate the extent of the corporate headquarters problem.

While North Carolina firms have been successful in attracting capital from outside the state, this capital has become increasingly concentrated both spatially and sectorally. As modern firms become increasingly reliant on public equity finance to pay for expansion and innovation, regional economies will become more dependant upon the opinions of investors. Improving the ability and willingness of North Carolina firms, particularly firms outside the FIRE sector, to participate in public equity markets is critical for the continued expansion of these firms, and in turn the state's economy, in the global economic system.

Notes

¹ North Carolina only has one dot com company, LendingTree.com of Charlotte. The firm's business consists of matching mortgage companies up with borrowers; it is simply an information broker. This business plan garnered the company a market capitalization of \$340 million at its peak in early 2000 but dropped to less than \$112 million in May 2001.

² To give these figures some perspective, Cisco Systems alone lost \$450 billion in market value between March 2000 and March 2001. Even after this decline Cisco's market value was \$138 billion (roughly equal to the market capitalization of Bank of America, First Union and Duke Energy together, North Carolina's three largest public companies).

In comparison to foreign direct investment the volume of equity investment in firms headquartered within the state (\$239 billion) dwarfs (by nearly a factor of 10) the \$24 billion in foreign direct investment that had accumulated in the state up to 1997 (Bureau of Census 2001).

³ In March 2000, US stocks were valued at 181% of gross domestic product, up from 60% in 1990.

⁴ Both Delhaize America and Centura Banks have been acquired by foreign firms since January 2001.

⁵ At its peak in 2000 Red Hat reached \$23.5 billion in market capitalization, making the company a large capitalization technology firm for a brief period.

⁶ First Union and Wachovia completed a merger in September 2001. The new company took the Wachovia name and is headquartered in Charlotte.

⁷ For the purposes of this paper technology firms are defined as operating in the following industries: Instruments and Related Products, Electronic Equipment, Industrial Machinery, Chemicals, Communications, Business Services (including software), Health Services, Engineering and Management Services.

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The Stroke Belt Enigma Continues: Reflections on the Geography of Stroke Mortality

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Suffering a stroke is devastating. The occurrence of this illness and the resulting loss of life in the U.S. are astronomical. While the mortality rates from strokes have plummeted dramatically over the last fifty years, especially in the Southeast, strokes continue to be menacing, as morbidity rates have remained virtually unchanged in decades. Current patterns of stroke mortality for whites, blacks, males, and females do support the notion that the stroke belt in the Southeast is becoming more fragmented and that a secondary stroke belt is becoming established along the Mississippi and Ohio River valleys. An examination of the literature on the geographic distribution of stroke reveals that physicians have written much of this research. While their interest in geography is to be applauded, the search for the stroke belt or belts would be best accomplished through multidisciplinary research teams consisting of physicians, epidemiologists, and geographers. Future studies on the geography of stroke should focus on morbidity, as these rates have remained stable for several decades.

Introduction

Physicians, epidemiologists, and other nongeographers have largely been responsible for identifying and exploring the stroke belt – a region of excessively high rates of stroke mortality occurring within the coastal plains of North Carolina, South Carolina, and Georgia. As yet, these studies have not been able to determine the causal factors responsible for this concentration. To their credit, physicians and epidemiologists have recognized the importance of a geographic perspective. Nevertheless, these same studies often fail to examine the appropriateness of the selected geographic techniques and concepts employed. Therefore, this article 1) examines risk factors, trends, and geographic distribution of stroke mortality and morbidity rates, 2) traces the origin and usage of the term “stroke belt,” 3) assesses the usage of such concepts and techniques as region, scale, data classification, choropleth mapping, autocorrelation, and mi-

gration effects from selected stroke studies, and 4) analyzes the current status of this stroke belt in North Carolina and the United States.

Risk Factors, Trends and Geographic Distribution

The primary risk factors for stroke are older age and hypertension. Other factors are relatively less important. However, among the more important of these secondary factors are high fat diet and lack of exercise that likely exert their effects through blood pressure and cholesterol levels. Socioeconomic status is likely to exert its effect similarly at least in part – it is a proxy for poor diet, hypertension, and no exercise. This link is supported by Meade’s (1979, 471) finding from Savannah, Georgia, “that the usual racial difference in blood pressure that has been repeatedly found when residences are classified only as urban, suburban, or rural disappeared when the teenagers were classified according to the land

use where they lived (i.e., blood pressure for whites and blacks living in a tract classified as 80% industrial did not differ significantly)."

The age-adjusted death rates from stroke experienced dramatic declines from 1950 to 1990 in the United States. Total age-adjusted death rates have plummeted from 88.8 per 100,000 to 27.7 per 100,000. Declines in these rates have been experienced by all sex/race groups, although blacks continue to experience higher death rates than whites. For example, the age-adjusted stroke mortality rate for white males was 87.2 per 100,000 in 1950 and 27.7 per 100,000 in 1990 while the rate for black males was 146.3 per 100,000 in 1950 and 56.1 in 1990. The phenomenon of declining rates may be ceasing in the 1990s as reflected by the minimal decreases in the age-adjusted death rates among whites and modest decreases among blacks from 1990 to 1995 (CDC 1997).

Since the 1960s, there have been numerous studies dealing with the geographic variation in deaths from strokes (see Table 1). Studies have been undertaken at the scale (i.e., the study area) of one or more states (Sauer et al. 1966; Siegel et al. 1992) or more commonly at the scale of the conterminous United States. Geographic units of analysis used in these studies included the individual states, the state economic areas (SEA), the health service areas (HSA), and the counties within each state. Time periods of interest ranged from 1939-1941 to 1988-1992 (Lanska 1993; Pickle et al. 1997). Further, mortality data for these studies were aggregated into one year (CDC 1992; Lanska and Kryscio 1994; Casper et al. 1995), three years (Sauer et al. 1966; Mason et al. 1981; Wing et al. 1988; Pickle et al. 1997), and five or greater years (Borhani 1965; Heyman et al. 1976; Fabsitz and Feinleib 1980; Siegel et al. 1992; Lanska 1993; Lanska and Peterson 1994; Howard et al. 1995; Pickel et al. 1997) for various race/sex groups (Jones et al. 2000; MMWR 2000). Such aggregations as quartiles, quintiles, deciles, and others were used to group data for the purpose of mapping stroke mortality rates (Table 1). A limited number of papers attempted to determine

the significance of disease clusters using autocorrelation area statistics (Borhani 1965; Lanska 1993; Lanska and Kryscio 1994; Lanska and Peterson 1994).

Most studies have reported high stroke mortality rates among populations within counties of the Southeastern Coastal Plain; hence, this region is often referred to as the "stroke belt." Recent studies, though, vary as to the current status of the stroke belt. Some investigators suggest that the stroke belt is shifting. According to Wing et al. (1988), high stroke mortality rates became less concentrated within the original stroke belt, whereas new areas of clustering of high rates became evident in areas adjacent to the southern Mississippi River and Ohio River from 1962 to 1982. Others suggest the stroke belt phenomenon persists. Pickle, Mungiole, and Gillum (1997) noted that although the rates for the Texas, Oklahoma, Arkansas, and Louisiana were high in 1988-1992, the Southeast still experienced high rates, especially for blacks. Howard et al. (1995) reported that the "relative increased risk of stroke death in the region has remained constant from 1968 to 1991" (p. 1153). It should be noted that these conflicting interpretations arise, in part, from the geographic unit and, more importantly, from the methods of data classification and spatial analytic techniques employed.

The Stroke Belt

The stroke belt is an ill-defined geographic region. For example, the National Heart, Lung, and Blood Institute considers states where stroke mortality rates are greater than 10% above the national average to be stroke belt states. Under this definition and using data from 1989, Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia would constitute the stroke belt (Lanska and Kuller 1995; Siegel et al. 1992). At the other end of the spectrum, many consider the traditional stroke belt as being a rather localized concentration of extreme rates among counties of the coastal plains of North Caro-

Table 1. Selected studies on geographic variations of stroke mortality

Author(s)	Geographic Unit	Time Period	Race/Sex Group	Data Classification	Statistics
Borhani	State	1949-1951, 1959-1961	WF, WM	Quartiles	Geary's C
Lanska	State	1939-1941, 1949-1951, 1959-1961, 1969-1971, 1979-1981	BF, BM, WF, WM	Significant deviations from the national level and 10th and 90th percentiles	Moran's I
Lanska and Kryscio	State	1989	Total population	Quartiles	Moran's I
Lanska and Peterson	State	1979-1981	W	Quartiles	Moran's I
CDC	State	1988	Total populaion	Quartiles	--
Casper et al.	State economic area	1962, 1975, 1988	BF, BM, WF, WM	Deciles (1, 2, 3-8, 9, 10)	--
Wing et al.	State economic area	1962-1968, 1969-1975, 1976-1982	WF, WM	Deciles (1, 2, 3-8, 9, 10)	--
Mason et al.	State economic area	1965-1971	NWF, NWM, WF, WM		
Heyman et al.	State economic area	1969-1971	BF, BM, WF, WM	--	--
Sauer et al.	State economic areas (NC, GA)	1950-1959	WM	Arbitrary (highest and lowest death rates)	--
Pickle et al.	Health service regions	1988-1992	BF, BM, WF, WM	Deciles (1, 2, 3-4, 5-6, 7- 8, 9, 10) and Quintiles	--
Fabsitz and Feinleib	Counties	1968-1971	BF, BM, WF, WM	Quartiles	--
Siegel et al.	Counties	1979-1981	Population	Exogenous	--
Howard	"stroke belt" counties	1968-1971, 1972-1975, 1976-1979, 1980-1983, 1984-1987, 1988-1991	BF, BM, WF, WM	--	--

Notes: BM= black males, BF= black females, WM= white males, WF= white females, W= white, NWF= non whit females, NWM= non white males

lina, South Carolina, and southern Georgia. Notwithstanding problems with its various definitions, Lanska and Kuller (1995) view the term "stroke belt" as a convenient buzzword for promoting stroke awareness and education.

Borhani (1965) was one of the first to document this clustering of stroke mortality for white men and white women for the years 1949-1951 and 1959-1961. How long it existed prior to that time is unknown. While the national age adjusted death rate for white males was 70.4/100,000, rates for the southeast Atlantic states ranged from 109.1 to 128.2/100,000 during 1949-1951. In other words, white males in the stroke belt states had a 1.5 to 1.8 greater risk of stroke mortality than the national average. Since then, numerous studies examining data across various geographic units, race/sex groups, and time periods have confirmed the existence of a stroke belt. Yet, the causal factors generating the stroke belt remain an enigma (Howard et al. 1995; Meade 1979). Repeated studies have indicated that the stroke belt is neither an artifact of systematic bias or error in diagnosis and death certificates (Casper et al. 1995) nor a result of variations in standards of care (Lanska and Kuller 1995). Other potential factors have been suggested including linkages to syphilis, alcohol consumption, elevated hematocrit, physical inactivity, obesity, and/or sickle cell disease. However, these factors either do not vary significantly or exhibit small variations regionally, have inconsistent associations with stroke, have affected just one race or gender, or have not been implicated with strokes (Lanska 1993). Connections between physical properties, such as selenium deficiency, water hardness, climate, and latitude and longitude, and the existence of the stroke belt have also not been confirmed (Fabsitz and Feinleib 1980; Meade and Earickson 2000).

Recently there has been disagreement as to whether the location of the originally identified stroke belt is stable or becoming less concentrated and shifting elsewhere. For example, Howard et al. (1995) asserted that the relative risk of stroke mortality among populations of the coastal plain of North Carolina, South Carolina, and Georgia

remained constant from 1968 to 1988. Pickle, Mungiole, and Gillium (1997) suggested that the rapid decline in stroke mortality rates for whites in the Southeast has left the West South Central states with relatively high mortality rates. Wing et al. (1988) mentioned that the stroke belt has become less concentrated in the coastal plain areas of the south Atlantic states and has become more pronounced along the Mississippi and Ohio River valleys.

Geographic Considerations

What exactly is the stroke belt? Answering this question is problematic. First, the stroke belt is arbitrarily defined as an area of the country in which there is an excess of stroke mortality as compared to the national average. The stroke belt sometimes refers to a broad region encompassing the southeastern states and at other times to the coastal plain counties of North Carolina, South Carolina, and southern Georgia. Too often the stroke belt is viewed as a fixed geographic region. As geographers know, one of the characteristics of regions is that they change over time. Others suggest that the borders of this region are indeed shifting (Casper et al. 1995) or that there are multiple stroke belts corresponding to the various categories of stroke. These different perspectives contribute to the current confusion about the areas that define the stroke belt.

Choropleth maps are the most common map type used to present stroke mortality data. However, there have been no attempts to promote optimal methods of classifying stroke data. The variety of classification methods used to develop categories to map stroke mortality rates is mind-boggling. These range from using quartiles, quintiles, standard deviation, percentiles, deciles, and other, sometimes arbitrary methods. Virtually all studies have neglected to indicate the appropriateness of their choice of data classification. Dent (1985) recommends appropriate data classification methods for specific data distributions. For example, he suggests using standard deviation units for data with normal distributions, equal class intervals for uniform distribu-

tions, geometric progressions for J-shaped distributions, and natural breaks or the iterative method for multi-modal distributions (data with two or more clusters of observations).

Two problems arise if data classification methods are chosen haphazardly. First, it is difficult to compare across studies that use a wide range of classification methods. Second, and probably more serious, employing autocorrelation statistics to test for clusters derived from less than optimal classification methods is inappropriate. That is, the finding of positive autocorrelation is meaningless when the pattern being tested is the result of an inferior or inappropriate classification. Uses of autocorrelation statistics by some authors have perhaps led to erroneous conclusions on the clustering of stroke (Lanska 1993; Lanska and Kryscio 1994; Lanska and Peterson 1995).

Probably the most exciting contributions regarding the stroke belt have been studies concerning the potential effects of international and interstate migration on the geographic distribution of stroke mortality (Lanska and Peterson 1995; Lanska 1997). Comparison from 1979 to 1981 found that "immigrants had markedly and highly statistically significant lower age-adjusted stroke mortality rates than either the entire US-born resident population or the US-born inter-regional migrant population" (Lanska 1997, 53). Similarly, comparisons were made between states' stroke mortality rates for native and resident populations. States either benefited or suffered from the influx or exodus of migrants. Although their study found that migration alone couldn't explain the existence of the stroke belt, Lanska and Peterson indicated that some states were strongly influenced, either in a positive or negative manner, by the effects of migration. Lanska and Peterson (1995) went on to identify Colorado and DC as benefiting from the migration of whites. In these two entities, out-migrants with high rates were improving the remaining population's stroke mortality rate. Conversely, they found that in states like California, Idaho,

Oklahoma, and Nevada, the mortality rates suffered from white migration, the first three states because of an influx of higher rate in-migrants and Nevada because of the exodus of lower rate out-migrants. For blacks, only Colorado benefited from the migration effects, whereas 21 states suffered.

Lanska and Peterson (1995) noted three effects that can influence mortality rates. These include the selection, origin, and destination effects. The selection effect is represented by the migration of healthy retirees to the Sun Belt; whereas, the movement of blacks from the South to the North in the 1920s and 1940s through the 1970s illustrates the origin effects. The destination effects are the lifestyle changes that people might make on moving to a new region. Another example of such a migration effects is illustrated by Florida's elderly population. Siegel et al. (1992) identified much of north Florida as part of the stroke belt using data from 1979-81. They found that a continuing in-migration of healthy, upper income, and educated elderly with a low stroke risk to central and southern Florida kept its stroke rate below the national average. Further, Florida's out-migrants were more likely to be disabled elderly returning to be close to their children in other states. Florida's patterns of in- and out-migrations have left the counties of north Florida with rates of stroke similar to the adjacent stroke belt.

There are several other geographic or medical considerations in demarcating the stroke belt. These include comparing the geographic patterns of diabetes, ischemic heart disease, cigarette smoking, diet, and socioeconomic status, which are known to have some association with stroke. Lanska noted that the pattern of ischemic heart disease is focused on the Northeast and therefore does not correlate with the stroke belt. He also observed that the pattern of diabetes is "only loosely similar to that for stroke." (Lanska 1993, 1847). However, rates of cigarette smoking do exhibit a similar pattern as that of stroke – the Southeast with high rates. Diet is another con-

sideration. The traditional diet of the Southeast consists of corn bread, beans, lard – a high grain, low protein diet similar to that of Japan. Strokes were the leading cause of death in Japan from 1950 to 1980 until a dramatic lowering occurred in the early 1990s (Kinyo et al. 1999; Sarti et al. 2000). Since the rise of the South, diets have become more similar to that of the rest of the United States. Improvements in socio-economic status (SES) and access to health care services and treatment for diabetes and hypertension might have the effect of producing milder strokes that people have better chances of surviving. A more developed health services network also increased survivability and lowered stroke mortality in the stroke belt. Add the recent large immigration of northerners to the South and this might partly explain the declining stroke rates in the stroke belt states.

Current Pattern

The *Atlas of United States Mortality* devotes eight pages to stroke mortality, two pages each for white males, white females, black males and black females. These pages can be viewed or downloaded from <http://www.cdc.gov/nchs/products/pubs/pubd/other/atlas/atlas.htm>. The first page (plate) includes a color choropleth map produced using age-adjusted rates for 1988-92 by health services area. The classification method used to categorize the data is based on percentiles. Its legend lists seven rate categories: 10 percent (category 1- lowest), 10 percent (category 2), 20 percent (category 3), 20 percent (category 4), 20 percent (category 5), 10 percent (category 6), and 10 percent (category 7 – highest) of the rate distribution. The legend is also referenced with a comparative mortality ratio “defined as the HSA age-adjusted rate divided by the U.S. age-adjusted rate” (Pickles et al. 1996, p. 10). A graph showing the distribution of health service area (HSA) death rates is also included on this plate. The second plate includes three maps and a graph: death rates of each HSA compared to the US rate, smoothed death rates for age 40, smoothed death rates for age 70, and predicted regional

rates for smoothed rate maps.

For white males a tenuous and sometimes fragmented string of HSAs from North Carolina have a 1.36 to 2.31 greater risk for stroke mortality than the United States. There also appears to be a secondary string of HSAs in this highest category within the Mississippi River Valley, particularly in Arkansas and Tennessee. Smoothed death rates for the age 40 suggest a splitting or shift in the stroke belt toward Arkansas, Louisiana, Texas and Oklahoma. White women have a similar geographic pattern of stroke mortality as white men.

Some of the highest rates of stroke are for black men. These high rates are clustered within the eastern coastal plains of the Southeast; however, the focus tends to be on South Carolina and the immediate adjacent North Carolina HSAs. Other high rates for black men in North Carolina and Georgia appear to be more isolated. A secondary cluster of the highest rates is found in the HSAs on either bank of the Mississippi River from Louisiana, Mississippi, and Arkansas. Again, the pattern for black females is similar to that of black males, except to note that the cluster of HSAs with high rates in South Carolina and Georgia appear to be less fragmented, whereas the high rates along the Mississippi Valley appear to be a bit more scattered than for black males.

The North Carolina Center for Health Statistics publishes on-line *The North Carolina Health Atlas*. County-level data from 1994 through 1998 were used to construct age-adjusted mortality rates per 100,000 population for cerebrovascular diseases (Figure 1, <http://www.schs.state.nc.us/maps/atlas/vstats98/cerebro.html>). Seven counties including a cluster of five were classified into the highest category with rates ranging from 112.1 to 121.5. From northeast to southeast, this cluster consists of Lenoir, Jones, Duplin, Sampson, and Bladen Counties. These counties are ranked low for median family income (2000) and population per physician. For context, compare the ex-

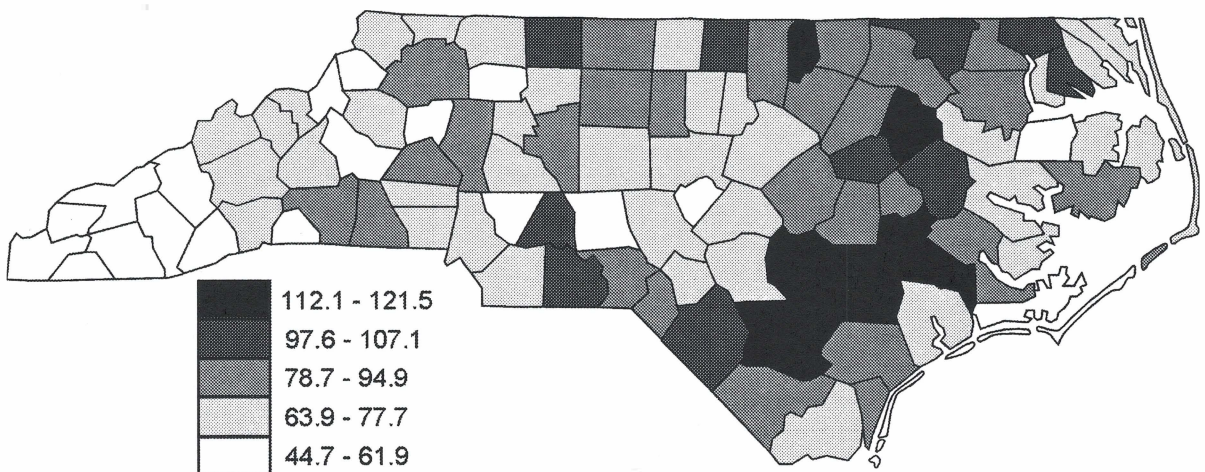


Figure 1. Age-adjusted mortality rates per 100,000 population North Carolina 1994-1998. Data from The North Carolina Health Atlas, North Carolina Center for Health Stateistics (1998).

treme differences that exist between Bladen County and Wake County for median family income and population per physician (Table 2).

Conclusions

Suffering a stroke is devastating. The occurrence of this illness and the resulting loss of life in the US are astronomical. While the mortality rates from strokes have plummeted dramatically over the last fifty years, especially in the Southeast, strokes continue to be menacing, as morbidity rates have remained virtually unchanged in decades. Current patterns of stroke mortality for whites, blacks, males, and females do support the notion that the stroke belt in the Southeast is becoming more fragmented and that a secondary stroke belt is becoming established along the Mississippi and Ohio River valleys. An examination of the literature on the geographic distribution of stroke reveals that physicians have written much on this topic. While their interest in geography is to be applauded, the search for

the stroke belt or belts would be best accomplished through multidisciplinary research teams consisting of physicians, epidemiologists, and geographers.

Traditionally, epidemiologists use geographic distributions of disease to infer etiology. For stroke, we know the major etiology: uncontrolled hypertension and age. Hence, the mapping of the stroke belt could prove useful for health care planning and intervention. Future research could seek to identify (predict) emerging regions of concern. Another research focus could be to verify the reasons for the higher rates of stroke with emphasis on the hypertension hypothesis. For this, one might want to focus on the emerging regions to identify what changes have occurred in terms of the regional population's health characteristics and behaviors. Third, there is an intervention agenda for future research. Specifically, the stroke belt could be targeted for community-based interventions: stroke awareness (signs of stroke so the victim gets to the hospi-

Table 2. Median Family Income and Population/Physician Ratio for North Carolina Counties with Highest Stroke Mortality Rates for 1994-1998.

Counties	Median Family Income (2000) Rank N=100	Population/ Physician Ratio
Vance	77	769
Edgecombe	40	1,501
Lenoir	59	594
Jones	No Data	No Data
Duplin	80	1,171
Sampson	70	1,259
Bladen	99	1,628
Wake (for comparison)	1	446

Source: Economic Development Information System, NC Department of Commerce <http://cmedis.commerce.state.nc.us/countyprofiles>.

tal sooner-this is actually the brain attack campaign of the National Stroke Association); promoting of prevention activities (i.e., exercise, diet); and especially medical treatment to control hypertension. Continued mapping, then, may be a cost-effective mechanism to monitor intervention impacts. Future studies on the geography of stroke

should also focus on morbidity rather than mortality rates, as the former rates may be more indicative of etiology than access to health care.

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Race, Class, Political Capacity and the Spatial Distribution of Swine Waste in North Carolina, 1982 - 1997

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The emerging national controversy over the socio-economic and environmental impacts of corporate pork production on rural communities raises claims of environmental injustice. Over the past two decades, the US swine industry has undergone a dramatic restructuring, expansion, and vertical integration of its pork production systems throughout North America, locating in peripheral, rural locations like North Carolina where environmental costs can be more easily externalized on to marginalized populations. We examine the relationships between key environmental justice variables—race, class, and local political capacity—and the spatial concentration of swine waste in the Black Belt region of the state and assess, empirically, claims of environmental inequity central to this emerging national issue. Analyzing the growth and concentration of swine production in eastern North Carolina between 1982 and 1997, we find clear cross-sectional and longitudinal evidence that minority communities and localities lacking the political capacity to resist are shouldering the bulk of the adverse economic, social, and environmental impacts of pork industry restructuring. We also find that the relationship between poverty and swine waste concentration varies by region. In the eastern region where 95% of North Carolina's swine waste is produced, we find a strong direct relationship between poverty and concentrated swine waste, while in the rest of the state we find an inverse relationship.

Introduction

Twenty years ago the environmental justice movement emerged onto the American political landscape and continues to raise questions about who pays and who benefits from contemporary policies of economic growth, industrial development, and environmental protection (Edwards 1995; Bullard 1996). More recently, emerging national contention over the socio-economic and environmental impact of agro-industrialization, especially related to pork production, clearly exemplifies these broader issues. By the mid-1980s, most sectors of American agriculture were well into an "industrial" transformation driven by the adoption of integrated production systems, capital intensive technologies, and increasing corporate control. Late to adopt corporate controlled, integrated production systems, the pork industry began to aggressively restructure production processes in the early 1980s and has since integrated itself into a global market

in which pork now accounts for over 40 percent of world animal protein consumption (Furuseth 1997; Thu and Durrenberger 1998: 8). By the late 1990s, the U.S. was producing 10% of the global pork supply and, by exploiting burgeoning markets in east Asia, the Russian Federation, and its NAFTA partners Mexico and Canada, was poised to overtake Denmark as the world's leading pork exporter. A ten-fold increase in pork exports since 1986, coupled with a modest 9.5% growth in pork's share of domestic meat consumption, has driven a sharp increase in the number of hogs produced annually, while over one-half million hog farmers went out of business nationally as their ranks declined from about 650,000 to 120,000 during the period examined here (NPPC 1999).

Hog farms have also changed dramatically since the 1970s when most hogs were raised on multiple-enterprise, crop-livestock farms with an average herd size of 150 hogs that provided an important, but

usually secondary source of farm income (Agricultural Animal Task Force 1996; Furuseth 1997). Today the typical hog farm utilizes confined animal feeding operations (CAFOs) of the sort pioneered by poultry producers and frequently dubbed "assembly line swine" by those wanting to emphasize that swine CAFOs more closely resemble industrial facilities than the traditional farms of the recent past. Swine CAFOs often house in excess of 50,000 head, with operations of over a million head each under development in Utah and Idaho, yet herd sizes of 1,000 - 5,000 are more the norm (Furuseth 1997; NPPC 1999). Hog operations with 1,000 or fewer head comprise 62% of current hog farms, but their market share has steadily eroded in concert with industry restructuring from 32% of all hogs produced in 1988 to only 5% by 1997. Conversely, in 1997, hog operations with more than 5,000 head produced 63% of the nation's hogs, yet comprised only about 6% of all hog farms (NPPC 1999).

Current pork industry profitability rests in large part on the extraordinary economies of scale generated by recent restructuring and the adoption of new, capital-intensive, production technologies (Rhodes 1995). However, these same economies of scale, in conjunction with the intensifying geographic concentration of pork production, have produced equally extraordinary and troubling "externalities of scale" flowing directly from the downstream economic, social, and environmental consequences of current waste disposal practices (Furuseth 1997). Central to the emerging debate surrounding the recent transformation of pork production are more general questions about the uneven social and spatial distribution of risks and rewards associated with industrial restructuring. Are the "externalities of scale"—socio-environmental impacts—associated with swine waste concentrated in low-income and minority communities? Does local political capacity play a role in explaining the socio-spatial distribution of swine waste externalities? If so, have such patterns intensified over time as pork industry restructuring intensified?

The county level census and agricultural data assembled here document community characteristics and indicators of swine waste production beginning in

1982 when traditional patterns of pork production still held sway, through the period of rapid industry expansion and restructuring, extending to the imposition of a statewide moratorium on new and expanded swine operations in 1997 (Edwards and Ladd 2000). The cross-sectional and longitudinal analyses presented here use an environmental justice framework to investigate the relationships between key environmental justice variables—race, class, and local political capacity—and the spatial distribution of externalities of scale associated with current swine waste disposal practices. Thus, it takes advantage of a unique opportunity to examine empirically claims of environmental injustice in the context of industry expansion and restructuring.

Swine Waste, "Externalities of Scale," and Environmental Justice

A recent Senate Agriculture Committee report documents that the annual volume of livestock wastes—including pork, poultry and beef—in the U.S. is approximately 130 times greater than annual production of human wastes. Moreover, recent reports indicate that such animal waste is now the largest contributor to pollution in 60% of America's rivers and streams classified as "impaired" by the U.S. Environmental Protection Agency (U.S. Senate, 1997; Office of Senator Thomas Harkin, 1997; Silverstein, 1999: 30). Nationally, contemporary swine CAFOs produce about 116 million tons of swine excreta and utilize an expanded and refined version of the waste disposal techniques characteristic of small-scale traditional hog farms. In the traditional system, indicative of the beginning of the period examined here, hog waste was collected and used to fertilize commercially viable field crops on the same farm. With reduced herd size and geographic dispersion of hog populations, the waste could essentially be laid on the land with little to no adverse consequences. In current practice, hogs are kept in confinement buildings where their liquid and solid excreta fall through slats in the floor and are periodically flushed away with water forming a liquid slurry. The slurry is then transferred to nearby waste lagoons as much as 25-30 feet deep and several acres in surface area. As needed to keep the lagoon from get-

ting too full, the slurry is applied to sprayfields with large irrigation sprinklers (see Furuseth 1997; U.S. EPA 1998 for more information).

Recent reports estimate that 10 million hogs produce nearly 20 million tons of swine waste in eastern North Carolina alone (Clean Water Network et al., 2000; Silverstein, 1999). However, swine waste is not categorized by the federal EPA as a hazardous or toxic material capable of damaging human health in relatively low doses. Thus, it is exempt from the Clean Water Act and many other environmental regulations that would apply to "point-source" polluters. Yet, the "externalities of scale" inherent in current swine waste disposal practices and its intensifying geographic concentration constitute a potential threat researchers and policy makers have just begun to investigate. What we term "externalities of scale" refers to a constellation of adverse, but not yet fully understood, economic, social and environmental impacts associated primarily with current pork production and waste disposal practices, but not present in the more dispersed, small-scale production practices typical at the beginning of the period examined here. Specifically these include economic impacts like the displacement of small farmers and the loss of property values, health impacts on those who work in or live in close proximity to CAFOs, and broader environmental impacts on air, soil, and ground and surface waters which can indirectly affect human and economic health in surrounding communities (Ladd and Edwards, 2001).

Since the early 1990s, the spatial concentration of corporate owned (vertically integrated) or contracted (horizontally integrated) hog operations in North Carolina has been framed by many environmentalists and minority activists as an environmental injustice. In such cases, people of color and the poor living in rural communities lacking the political capacity to resist are said to shoulder the adverse socio-economic, environmental, or health related effects of swine waste externalities without sharing in the economic benefits brought by industrialized pork production (United Church of Christ 1987; U.S. General Accounting Office 1995; Harris 1994, 1997; Wing et al. 1996; Wing et al. 2000; Wing and Wolfe 2000; Edwards and Ladd

2000). The cross-sectional and longitudinal analyses below assess these claims directly.

Theoretical Issues

In this section, we discuss pertinent issues related to regional differences, race/ethnic discrimination, local political capacity, and market factors in explaining patterns of environmental inequality. Much quantitative environmental justice research has examined residential proximity to hazardous waste streams or traditional industrial facilities, especially those associated with toxic and hazardous substances that are widely believed to harm human health (cf. Mohai and Bryant 1992). The case at hand diverges from existing research in two important respects. First, the restructuring and expansion of pork production sketched above has so thoroughly transformed the industry during the period of our analysis that we treat it as a "new" or emerging industry. Second, swine CAFOs are legally categorized as "farms" rather than "industrial" facilities, and livestock waste is not regulated as a hazardous or toxic material. Thus, they are "non-point source" polluters and exempt from the Clean Water Act and many other environmental regulations that would apply to industrial facilities, hazardous or toxic materials, and other "point source" polluters like municipal sewerage treatment plants (NRDC 2001).

Regional Concentration

The rural and agricultural nature of this emerging industry further differentiates our emphasis from the predominant focus in environmental justice research because the equity issues at stake in the agro-industrialization of swine production in North Carolina stem, in large part, from the historical political economy of North Carolina's eastern coastal plain as a distinct and peripheral region of the state (Roscigno and Tomaskovic-Devey 1994). The concentration of corporate hog farming has followed the path previously paved by cotton, tobacco, and poultry whereby production migrated to the counties of the eastern, coastal plain traditionally dependent on black, and poor white, agricultural labor (Wood 1986). Besides row crops, the region's economy has been dependent upon

extractive industries like fishing, mining, and pulp-wood forestry. Beginning in the early 1960s, the region has become home to some textile and light manufacturing as firms began to migrate out of northern industrial states to regions with lower taxes, lower wages, and weaker unions. Much of the region's economy has been controlled by outside interests. Despite improvements in recent years, the coastal-plain of the East remains the most economically distressed and arguably the most politically marginalized area of the state (ProjectEast 1993; RDI 2000). This region, which lies roughly to the east of Interstate 95, is home to just over 2 million people or 31% of the state population, yet in 1990 42% of North Carolina's poor lived in the East. At the beginning of the period examined here (1980), 25 of the region's counties had poverty rates over 20% and in 33 eastern counties blacks comprised more than 30% of the population. The East is also home to 44% of the state's African American residents, more than half (53%) of which are in poverty. In 1990, the region-wide poverty rate was 17.5%, but among African American residents it was 33%.

Eastern North Carolina has been profoundly affected by pork industry restructuring. In 1982 only one North Carolina county lacked commercial hog farms; by 1997, following the period of intensive restructuring examined here, approximately 95% of all swine production had concentrated in the eastern counties of the coastal plain. In light of these strong regional dynamics, the analysis below pays particular attention to region in explaining the distribution of swine waste externalities during the period of industry restructuring and globalization examined here.

Intentional or Institutional Discrimination in Environmental Justice Analysis

In our estimation, two problems characterize much of the recent empirical research on environmental equity relating to the conceptualization of injustice generally and racial discrimination in particular. Feagin (1977) distinguishes between direct and indirect discrimination. In the context of our analysis, direct discrimination would involve conscious and intentional decisions to locate large, CAFO-style hog operations

in minority communities. Hamilton (1995) characterized this definition as a "pure-discrimination model" of environmental racism and a number of environmental equity analysts use this definition (see for example Been 1994). By contrast, another group of analysts adopts a structural conceptualization of environmental racial inequality focusing on institutional processes that constrain, often indirectly, the capacity of minority individuals to resist forms of oppression (see for example Bullard and Wright 1987; Bullard 1990; Stretsky and Hogan 1998). Downey's (1998) replication of Bowen et al. (1995) indicates that similar empirical results lead to contrasting interpretations depending on whether one adopts an institutional, rather than a "pure discrimination," conceptualization. To find evidence of environmental racism in a "pure-discrimination" model, the analysis must demonstrate racist intent (no small task in statistical analysis). However, the presence of environmental injustice does not require a demonstration of intentional discrimination and proponents of 'institutional racism models' do not attempt to explain racially inequitable outcomes in terms of racist intent. They argue, instead, that the normal, non-intentionally discriminatory operation of important social institutions leads to racially inequitable outcomes. Therefore, a racially biased distribution of any environmental hazard is evidence, in and of itself, of environmental racism (Downey 1998: 769-770). For those using a racist intent model, such non-intentional outcomes are often treated as market-related and therefore "incidental" and not constituting discrimination (Been 1994: 17). Here, we adopt a structural and institutional framework to assess discriminatory impacts. Thus, we focus analytical attention on whether or not and to what degree low-income communities and communities of color (regardless of income) shoulder the environmental burdens and risks of recent pork industry restructuring and spatial concentration.

Local Political Capacity

A growing consensus exists among scholars about the factors that account for the emergence of collective action, and hence the capacity of specific localities to mobilize opposition to increasing environ-

mental inequalities. These include elements of political opportunity, as well as access to specific human, social and cultural resources (McAdam, McCarthy and Zald 1996). Difficulties in compiling systematic local data over time on fine-grained indicators of political capacity are daunting and quantitative environmental justice researchers have often relied on voter registration rates (Hamilton 1995). Though clearly not an ideal measure of political capacity, the logic has some merit since structural impediments to voter registration and turnout have traditionally constrained the political capacity of low-income groups and minorities (see Piven and Cloward 1988; Teixeira 1992). This is especially so in the South where for many long-term residents simply being registered to vote is itself the direct result of participation in local political mobilizations (Morris 1984; McAdam 1983). Other researchers have argued that the percent of residents with a college education would be a better measure of potential political mobilization on local environmental justice issues than voter registration rates (see for example, Hird, 1994:130-134). With respect to local collective action potential, "conscience constituents" comprised of sympathetic college educated residents are an important, but not always necessary, resource for local mobilization (McCarthy et al. 1988; McCarthy and Zald 1977).

What this body of research makes clear is that the normal functioning of the American political arena constrains the representation of marginalized, low-income, and minority constituencies, often excluding their concerns from public agenda setting altogether (Gaventa 1980). Following these factors, an environmental justice framework would predict that communities lacking political capacity constitute a path of less resistance and will suffer greater exposures to environmental risks and bear higher costs of externalities than those capable of mobilizing more effectively (Bullard and Wright 1987; Capek 1993). Thus, we expect to find a negative relationship between local political capacity and hog population size (cross-sectional) and hog population growth (longitudinal). Moreover, extending this logic would predict that localities whose political capacity had declined over this

period of restructuring and globalization would be expected to have experienced greater swine population growth.

Data & Measures

The spatial unit of analysis most suitable for empirical environmental justice research has been the subject of some debate and contention because of inconsistent findings and aggregation bias (Anderton 1996). Nevertheless, the county level of analysis is used here because comprehensive, longitudinal swine data is available only at the county level.¹ Thus, the data assembled here enable us to undertake a cross-sectional analysis of the relationship between community characteristics and hog population size at four time points spanning the key two decades of swine industry expansion and spatial concentration. It also enables a preliminary longitudinal analysis of changes in county hog population size during this period of industry restructuring commensurate with the globalization of the pork industry.

The data set used in this research was assembled from county level data compiled in the North Carolina LINC data base and NC Department of Environment, and Natural Resources Division of Water Quality (DWQ) data base on state swine operations. The LINC system combines county-level measures assembled from a wide array of state and federal agencies, including the U.S. Census Bureau, the Census of Agriculture, State Board of Elections, the NC Department of Commerce, and the State Department of Agriculture. The DWQ data are updated quarterly and represents the most reliable source of swine data for the state. State Department of Agriculture data on the number hogs and hog operations by county are used for 1977, 1982, 1987 and 1992. The 1997 swine data come from the October 15, 1997 DWQ quarterly report and reliably represents the state's swine population at the time the current moratorium on new and expanded hog operations went into effect. Because of the moratorium on new and expanded swine operations that went into effect in 1997 but is set to expire in 2003, our data accurately reflects the

current spatial distribution of swine waste in North Carolina (Ladd and Edwards 2001).

Dependent Variables

We use two dependent variables in the analysis presented below. County-level hog population size is used in the cross-sectional analysis, while the preliminary longitudinal analysis examines the percent change in hog population size between 1982 and 1997. We chose to examine patterns of concentration in hog

populations rather than in hog operations in part because we want to shift the analytical focus to inequitable environmental outcomes, rather than individual facility siting decisions. Also, as depicted in Figure 1, mean herd size grew from 187 head in 1982 to 2,109 head in 1997 representing more than a 1000% increase in the waste potential of a typical hog operation over the period studied here. Moreover, contemporary commercial hog operations vary greatly in size. Thus, herd size and, by extension, county-level hog population

Figure 1

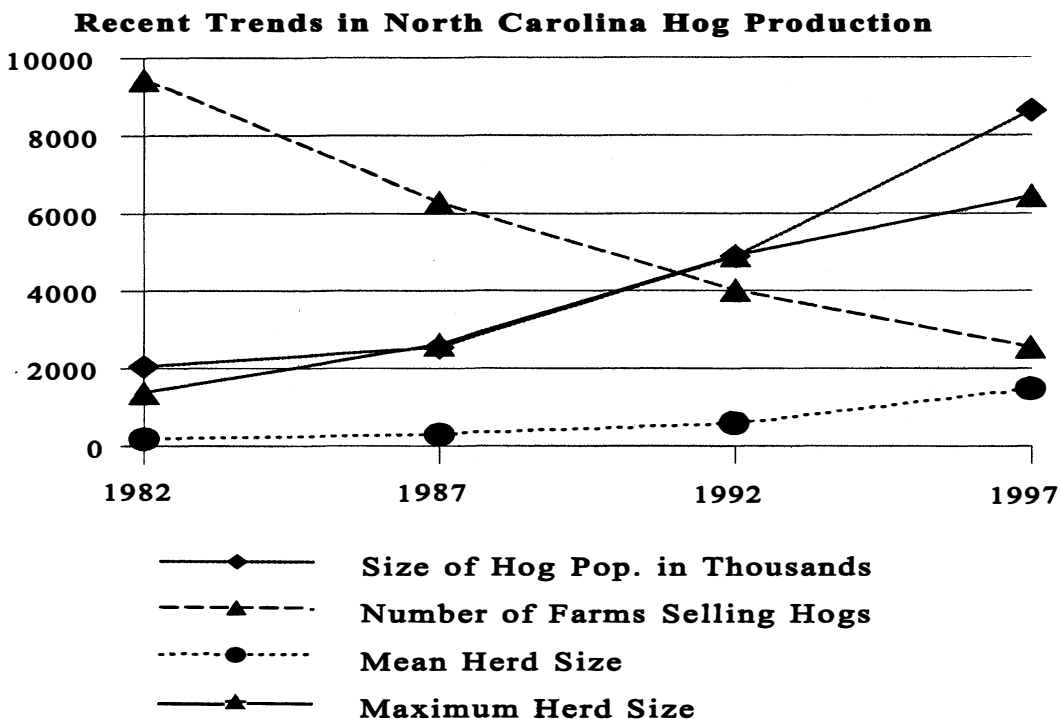


Table 1:
North Carolina County Characteristics and Hog Population
(A Comparison of Eastern to Other Counties)

County Characteristics	All Counties (N=100)		Eastern Counties (N=41)	Other Counties (N=59)	Means Ratio
County Attributes	Mean	(SD)	Mean	Mean	(East/Other)
Hog Population					
Hog Population, 1982	20,471	57,982	40,378	6,637	6.1 **
Hog Population, 1987	25,407	32,875	54,328	7,731	7.0 **
Hog Population, 1992	48,861	161,325	111,378	5,417	20.6 **
Hog Population, 1997	86,221	283,460	203,076	5,017	40.5 **
Environmental Justice					
Percent Not White, 1980	24.8	17.1	36.3	16.7	2.17 **
Percent Not White, 1990	24.5	17.2	35.6	16.8	2.12 **
Percent Residents in Poverty, 1980	13.1	2.0	21.0	15.1	1.39 **
Percent Residents in Poverty, 1990	23.8	4.1	18.5	13.7	1.35 **
Local Political Capacity, 1980	37.9	5.7	35.3	39.7	.89 **
Local Political Capacity, 1992	41.9	5.8	39.6	43.5	.91 **
Control					
Percent Urban, 1980	26.2	24.6	25.3	26.9	.94 ns
Percent Urban, 1990	27.1	24.7	26.3	27.7	.95 ns
Median Property Value, 1980	32,700	6,300	30,100	34,100	.88 **
Median Property Value, 1990	57,600	13,400	54,300	59,800	.91 *
Unemployment, 1977-81	6.6	1.5	7.1	6.3	1.11 **
Unemployment, 1982-86	8.3	2.8	8.6	8.0	1.08 ns
Unemployment, 1987-91	5.2	2.1	5.5	4.9	1.12 ns
Unemployment, 1992-97	5.9	2.4	6.6	5.4	1.22 **
Annual Wages, 1980	10,470	1,490	10,070	10,750	.94 *
Annual Wages, 1990	17,130	2,600	16,210	17,790	.91 **

* $p \leq .05$, ** $p \leq .01$

are more direct and preferable indicators of the environmental externalities and potential risks associated with swine waste than using the number of hog operations.

Hog Population 1982, 1987, 1992, 1997 indicates the approximate number of all commercially raised hogs alive in each county on any given day in each of the years listed.² In 1997, this ranged from zero hogs in some counties to 1.65 million and 2.11 million head in Sampson County and Duplin County respec-

tively. Because the distribution of this variable is so skewed—with a mean 1997 county hog population of 86,221 and a standard deviation of 283,460—the base 10 logarithm is used to reduce skewness in the dependent variable and prevent the analyses from being distorted by the characteristics of outlier counties.

³ In the longitudinal analysis, we examine the percent change in logged hog population size from 1982 when traditional hog farming still prevailed, to 1997 when the current state moratorium went into effect. The

means and standard deviations of variables used in the analyses are presented in the first two columns of Table 1.

Environmental Justice and Control Variables

The environmental justice framework predicts that the externalities of scale associated with the restructuring, expansion, and spatial concentration of pork production would fall disproportionately on lower income counties with higher proportions of nonwhite residents. Moreover, in the longitudinal analysis, such communities are expected to experience intensifying concentrations of swine waste externalities. We use the following two variables to investigate these claims. Percent Not White refers to the percent of each county's population comprised of people of color.⁴ Percent in Poverty measures the proportion of county residents living below the federally established poverty threshold in 1980 and 1990.

As argued above, we also expect the adverse impacts of swine waste externalities to follow a path of least political resistance settling in communities with less capacity to resist.

Thus, given the limitations of currently available local data, we use a proxy indicator of Local Political Capacity that combines the percentage of eligible adults in each county who were registered to vote with the percentage of county residents with a four-year college degree.⁵ Clearly this is a less than ideal measure of local political capacity. A preferred measure would, for example, identify environmental and other issue advocacy organizations in each locality and construct measures of rates of such organizations per 1,000 residents. A similar strategy worked well in Bebbington's (1997) case study analyzing mobilization capacity for sustainable development in the rural Andes. Another strategy would follow the lead of Flora, et al. (1996) who developed measures of "entrepreneurial social infrastructure" in over 1,000 small municipalities as a means of explaining which communities were more or less likely to undertake local economic development initiatives. The prospect of constructing either of these kinds of measures over the 15 year time frame of this analysis is no simple matter. Thus, for the purposes of this analysis we

use the measure described above as an exploratory proxy to see if the results here motivate the data building efforts needed to construct more robust and satisfying measures. In the longitudinal analysis below (Table 4), Change in Political Capacity measures the percent change in Local Political Capacity between 1980 and 1992.

Columns 3 and 4 of Table 1 present the mean values of the variables used in this analysis for the 41 eastern counties and the 59 other counties in the state. The last column presents the means ratio and results of an independent samples T-test of differences between the mean values for each region. Tables 2 – 4 present results from bi-variate and multiple regression analyses. In light of the consistent regional differences, especially related to the key environmental justice variables, we use a dummy coded control to differentiate between the East Region (1) and other (0) counties. To test our expectation about regional differences in the relationship between poverty and swine waste, we constructed an interaction term In-Region Poverty (East * Percent Poverty). Doing this enables us to examine the effects of poverty separately for each region. In the models that contain this interaction term, the main effect for Percent living in poverty represents the effect of poverty outside of the East Region. By contrast the coefficient for In-Region Poverty represents the effect of poverty within the 41 counties of eastern North Carolina.

Population density, often measured as the number of residents per square mile, has been suggested as part of an alternative explanation in environmental justice analyses of hazardous waste site location and residential exposure to toxic releases with mixed results (Kriesel et al., 1996; Yandle and Burton, 1996). Through the period of this study, North Carolina has been one of the fastest growing states in the U.S. with most new population growth concentrated in metropolitan areas and urban municipalities. Thus, counties that have become increasingly urbanized over the last two decades may be less likely to also have either larger or growing hog populations. Thus, we use the percentage of county residents residing in urban areas in 1980 and 1990 to control for Urbanization. We also include additional controls for property values and

Table 2:
Bivariate Regressions (OLS) of Hog Population Size on County Characteristics

County Characteristics ^a	Environmental Justice ^c				Controls ^c		
	Percent Not White	Local Political Capacity	Percent Poverty	East (1 = Yes)	Percent Urban	Median Property Value (\$1,000)	Labor Market Attributes
1982 Hog Population							
Standardized Beta	.62 **	-.53 **	.26 **	.50 **	.16	-.29 **	.01
T Score	7.86	-6.14	2.66	5.67	1.59	-2.96	.04
Adjusted R square	.38	.27	.06	.24	.02	.07	-.01
1987 Hog Population							
Standardized Beta	.55 **	-.47 **	.20 *	.53 **	.12	-.22 *	-.09
T Score	6.55	-5.28	1.98	6.13	1.15	-2.24	-.85
Adjusted R square	.30	.21	.03	.27	.00	.04	.00
1992 Hog Population							
Standardized Beta	.49 **	-.55 **	.16	.49 **	.02	-.28 *	.01
T Score	5.50	9.83	1.60	5.49	.15	-2.90	.12
Adjusted R square	.23	.29	.02	.23	.00	.07	-.01
1997 Hog Population							
Standardized Beta	.60 **	-.54 **	.23 *	.58 **	.00	-.31 **	.13
T Score	7.33	8.55	2.35	7.13	.01	-3.27	1.30
Adjusted R square	.35	.28	.04	.33	.00	.09	.01

labor market attributes. Labor Market combines the average monthly unemployment rate in each county over the sixty months preceding each of the four time points in the analysis with its average annual wages, which reflects total earnings by place of work divided by total full and part-time employment for all industries. Labor Market is coded so that lower scores correspond with a more favorable business climate in terms of lower wages and higher unemployment rates.⁶ Property value measures the median value of owner-

occupied residences in 1980 and 1990 dollars respectively.

Results

Cross-Sectional Analysis

After briefly considering the bivariate regressions presented in Table 2, we examine the results of our multivariate cross-sectional analysis of county-level swine populations. The environmental justice and control variables are measured in 1980 and 1990 and

indicate county level attributes predating our measures of hog population size at each of the four points in time. Standardized coefficients are presented to facilitate comparisons of the relative strength of each variable in explaining patterns of swine waste concentration. Bivariate results for Percent Not White, Local Political Capacity, and Percent Poverty are statistically significant and consistent with environmental justice expectations except for Percent Poverty in 1992. We also find evidence of strong regional effects with East Region, a consistent positive predictor of greater swine waste concentration. Among the control variables, higher Property Values generally predicts smaller hog populations as expected, while Labor Market and Percent Urban evidence no relationship with hog population size.

We turn now to the multivariate cross-sectional analysis presented in Table 3 which identifies county-level attributes associated with subsequent hog population size and thus the concentration of externalities associated with swine waste. Given the relatively small number of cases ($N=100$) in this analysis, we limit our models to a maximum of one predictor for every ten cases (London 1988). Thus, our multivariate analysis uses the following strategy.⁷ For each of the four time periods examined, Model 1 includes our three key environmental justice variables and the dummy coded East Region ($East = 1$). Model 2 then steps in the In Region Poverty interaction to test our hypothesis about a region specific poverty effect and to better assess any changes over time in the ability of race and class to predict subsequent patterns of swine population concentration. In Model 3, we step in three control variables—Percent Urban, Property Values, Labor Market—to assess whether or to what extent the relationships between the primary environmental justice and region variables are altered. In order to facilitate comparisons of the relative strength of different variables in predicting patterns of swine waste concentration, we present standardized Betas in Table 3.

Before examining the results with respect to the specific hypotheses described above, we begin by briefly discussing the fit of our models. First, we note that the adjusted R squares for Model 1 range from .40 to .55 indicating that our base model of environmental justice variables and region explains county-

level hog population size acceptably well. Across the first three time periods examined here, Model 2 improves notably upon Model 1, while the addition of control variables in Model 3 does not notably improve upon the fit of Model 2 in any of the periods examined here.

Local Political Capacity. The environmental justice framework predicts that environmental inequalities of all sorts would follow a path of least political resistance. Commensurate with this we expected to find an inverse relationship between local capacity for political mobilization and swine waste concentration at subsequent points in time. The results for Local Political Capacity are consistent with the path of least political resistance hypothesis across all four time periods examined here. The strength of this effect in Model 1 is consistently enhanced by stepping in the In Region Poverty interaction (Model 2), and generally diminished somewhat by adding the block of control variables (Model 3).

Percent Not White. The environmental justice framework claims that contemporary effects of historic discrimination in conjunction with current processes of institutional and intentional discrimination cause people of color to be more likely than whites to experience environmental inequalities. We expected to find greater concentrations of hog waste in counties with higher proportions of minority residents. Results for Model 1 are consistent with this expectation in each time period examined here. Counties with larger communities of color have larger hog populations and thus have had to absorb intensified externalities of scale from swine waste. However, the relationship between race and poverty and their effects on subsequent hog population size are complicated significantly by regional differences. When the In Region Poverty interaction is stepped in (Model 2), the effect of Percent Not White is reduced to nonsignificance for 1987 and 1992. Yet, in 1997, following the period of greatest hog population growth (1992-1997), Percent Not White remains a significant predictor of swine waste concentration. The effect of Percent not White becomes stronger after stepping in the block of control variables (Model 3).

Poverty and In Region Poverty. Another core environmental justice claim predicts that independent of

Table 3:
Multiple Regression (OLS) of Subsequent Hog Population on County and Hog Operation Characteristics^a

County Characteristics ^b	1982 Hog Population			1987 Hog Population			1992 Hog Population			1997 Hog Population		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Environmental Justice												
Pct. Pop. Not White	.45 ** (3.95)	.24 * (2.13)	.22 ** (1.93)	.37 ** (3.11)	.18 (1.49)	.17 (1.37)	.28 ** (2.58)	.13 (1.07)	.17 (1.29)	.38 ** (3.85)	.28 * (2.60)	.37 ** (3.12)
Local Political Capacity	-.27 ** (-2.85)	-.31 ** (-3.58)	-.28 ** (-2.99)	-.17 + (-1.74)	-.21 * (-2.25)	-.20 * (-1.98)	-.37 ** (-4.24)	-.40 ** (-4.64)	-.42 ** (-3.70)	-.31 ** (-3.86)	-.32 ** (-4.08)	-.28 ** (-2.73)
Percent Living in Poverty	-.08 (-.79)	-.35 ** (-3.08)	-.29 * (-2.20)	-.22 * (-2.00)	-.46 ** (-3.81)	-.43 ** (-3.09)	-.11 (-1.06)	-.30 * (-2.50)	-.28 + (-1.67)	-.14 (-1.50)	-.26 * (-2.38)	-.39 * (-2.42)
Eastern Counties	.16 (1.40)	-1.20 ** (-3.81)	-.99 ** (-3.00)	.36 ** (3.08)	-.87 * (-2.58)	-.73 * (-2.08)	.25 * (2.29)	-.58 + (-1.92)	-.53 (-1.46)	.32 ** (3.31)	-.21 (-.75)	-.12 (-.36)
In Region Poverty												
East * Poverty Rate	—	1.69 ** (4.55)	1.45 ** (3.76)	—	1.53 ** (3.84)	1.36 ** (3.31)	—	1.07 ** (2.91)	.99 * (2.38)	—	.68 * (2.02)	.60 (1.54)
Control Variables												
Percent Population Urban	--	--	.01 (.10)	--	--	-.09 (-.80)	--	--	-.15 (-1.45)	--	--	-.13 (-1.33)
Labor Market	--	--	-.18 + (-1.68)	--	--	-.18 (-1.48)	--	--	-.09 (-.72)	--	--	.02 (.14)
Median Property Values	--	--	-.20 + (-1.83)	--	--	-.14 (-1.12)	--	--	.03 (.17)	--	--	-.05 (-.34)
Adjusted R Square	.45	.54	.55	.40	.48	.48	.42	.46	.46	.53	.54	.55
F Score	21.25	24.66	16.18	17.58	19.05	12.30	18.85	17.95	11.40	28.57	24.40	15.81
Degrees of Freedom	95	91	90	95	91	90	95	91	90	95	91	90

+ $p < .05$ (one-tailed), * $p \leq .05$, ** $p \leq .01$.

^a Coefficients are standardized Betas. Raw T scores in parentheses.

^b 1980 county characteristics are used in the analyses of 1987 hog population, and 1990 characteristics are used for 1992 and 1997.

minority composition or political capacity, low income areas will experience greater environmental inequality than those populated by higher income residents—and our bivariate results (Table 2) are consistent with this expectation. However, the results for percent poverty in a multivariate model (Model 1, Table 3) that includes the three environmental justice variables and region are not consistent with this expectation at any of the four time points. In fact, we find just the opposite in 1987 when higher poverty rates predicted smaller hog populations. However, as discussed above, we expected that the effects of poverty rates on swine waste concentration would be complicated by differing regional dynamics and this expectation proved to be generally well founded as indicated by results for Model 2. Because we have the interaction term for In-Region Poverty in the model, the coefficient for Percent Poverty represents the effect of poverty outside of eastern North Carolina. Thus we see that across all four time points the direct effect of Percent Poverty in Model 2 indicates that outside of eastern North Carolina, where only about 5% of the state's hog population currently exists, higher poverty rates consistently predict smaller swine populations. However, Model 2, which includes the interaction between region and poverty rates, indicates that just the opposite is the case within eastern North Carolina where about 95% of the state's swine waste is currently produced. Within the East, there has been a strong positive relationship between prior household poverty rates and subsequent swine waste concentration as indicated by the results for In-Region Poverty in Model 2. To determine the size of the effect of In-Region Poverty the coefficient for the direct effect of poverty is subtracted from the coefficient for the interaction term. Thus, in eastern counties, the effect of poverty rates on the intensity of swine waste externalities is 1.34 (1.69 - .35), 1.07, .77, and .42 in 1982, 1987, 1992 and 1997 respectively. Thus, swine waste is more concentrated in the poorer counties of the state's poorest region, while outside of the East higher rates of poverty consistently predict smaller swine populations. When examining Model 2 across all four time periods, the in-region poverty effect remains significant, but diminishes steadily in strength as judged by the standardized Beta coefficients. Moreover, when

the three control variables are stepped in (Model 3), the strength of In-Region Poverty effect is also reduced. In 1997 following the period of greatest swine population growth and concentration, In-Region Poverty becomes nonsignificant ($p = .06$, one-tailed) after adding in the additional controls, despite the fact that none of those controls are significant.

Longitudinal Analysis

In Table 4 we present a longitudinal analysis of patterns of intensification in the spatial distribution of swine waste over the period of industry restructuring and globalization. In 1982 traditional patterns of pork production prevailed in North Carolina, but by 1997 total production had increased more than five-fold, the number of hog farmers had declined precipitously, and CAFO-style operations had become the norm with typical herd sizes in excess of 2,000 head. Moreover, all industry growth had occurred in the eastern region where a single vertically integrated, multi-national corporation controls virtually all pork production and processing statewide, reaping substantial profits. To the extent that industry critics are correct in arguing that current profitability is largely "pollution-based," resting on shifting the costs of swine waste externalities to the rural residents of North Carolina, this longitudinal analysis specifies which constituencies have borne an increasing share of these costs.

Model 1 includes key environmental justice variables and the interaction to specify regionally specific effects of poverty on the intensification of swine waste externalities. The results here are broadly compatible with the cross-sectional results presented in Table 3. Counties that began this period of industry restructuring with higher proportions of nonwhite residents experienced swine waste growth (.26) between 1982 and 1997. Similarly, counties with greater political capacity are also shouldering a decreased share of swine waste externalities (-.17). The relationship between poverty rates and swine waste intensification vary by region as they did in Table 3. Outside of eastern North Carolina, there is an inverse relationship (-.37), while within the east where over 95% of the state's swine waste is currently produced, the relationship is positive indicating that poorer counties in the eastern re-

Table 4:
Multiple Regression (OLS) of Hog Population Change on County Characteristics ^a

County Characteristics ^b	Hog Population Change, 1982 - 1997		
	Model 1	Model 2	Model 3
Percent Population Not White	.26 * (2.17)	-.34 ** (-2.72)	.35 ** (2.91)
Local Political Capacity	-.17 + (-1.78)	-.20 * (-2.09)	-.32 ** (-2.96)
Percent Living in Poverty	-.37 ** (-3.00)	-.56 ** (-3.99)	-.53 ** (-3.78)
Eastern Counties	-.08 (-.24)	-.09 (-.26)	-.14 (-.43)
In Region Poverty (Eastern County * Poverty Rate)	.67 + (1.67)	.68 + (1.72)	.70 + (1.81)
Percent Urban	---	-.18 + (-1.68)	-.23 * (-2.08)
Median Property Values	---	-.03 (-.26)	.09 (.69)
Labor Force Attributes	---	.11 (.90)	.12 (.98)
Change in Local Political Capacity (1980 - 1992)	---	---	-.21 * (-2.20)
Adjusted R Square	.44	.47	.50
F Score	15.95	11.75	11.44
Degrees of Freedom	95	92	91

+ $p \leq .05$ (one-tailed), * $p \leq .05$, ** $p \leq .01$.

^a Coefficients are standardized Betas. Raw T scores in parentheses.

^b 1980 county characteristics are used in the analyses of 1987 hog population, and 1990 characteristics are used for 1992 and 1997.

gion have shouldered increasing amounts of swine waste compared to the region's more prosperous counties.

In Model 2, we step in controls for urbanization, property values, and labor market attributes. This block of controls significantly improves the fit of the model to the data and increases the adjusted R square to .47. As expected in a rapidly growing and urbanizing state, counties that were already more urbanized in 1982 experienced declining swine waste concentrations over the subsequent period. However, adding the controls does not alter the pattern of results for the variables previously included in Model 1. In Model 3 we add an additional variable that measures the change in local political capacity between 1980 and 1992. The results indicate that increasing political capacity over the period is associated with decreasing swine waste concentrations (-.21). Model 3 improves significantly upon Model 2 and fits the data acceptably well with an adjusted R square of .50. Based on Model 3, our results offer clear support for the expectations of an environmental justice analytic framework. Counties with larger nonwhite populations saw their share of the state's swine waste increase over this period of industry restructuring. Poorer counties in the East experienced increased concentrations of swine waste, while swine waste levels in poorer counties outside the region saw swine waste levels decrease. Finally, this analysis points to the importance of local political capacity in explaining patterns of swine waste intensification. Counties that began the period of restructuring with less political capacity experienced swine waste intensification. Moreover, counties whose political capacity declined between 1980 and 1992 also experienced an intensification of swine waste externalities during the period of industry expansion and consolidation examined here.

Discussion

Institutional Discrimination

The results of this analysis offer clear evidence of discriminatory impacts by race and class such that counties with larger minority populations, regardless of income, have larger concentrations of hog waste despite controlling for regional differences, urbanization, property values, and labor force attributes. Counties

with more nonwhite residents had larger hog populations at each of the four time points examined here (Model 1). However the effect of race is related to the effects of poverty, as race becomes nonsignificant in 1987 and 1992 when the regionally specific measure of poverty is included in the model. However, by 1997, following the period of greatest hog industry growth and concentration, counties with more nonwhite residents were absorbing greater swine waste externalities despite the regionally specific poverty effect. Moreover, results from the longitudinal analysis (Table 4) clearly indicate that between 1982 and 1997, minority communities experienced greater hog population growth than did other counties.

Combining this pattern of swine population intensification in minority areas with the results of prior research linking county-level hog industry growth to increased rates of farm loss and black poverty, offers further evidence that African American communities have shouldered a greater share of environmental and economic costs imposed by the restructuring of pork production (Edwards and Ladd 2000). Consistent anecdotal reports from African American farmers across the region indicate that there are very few, if any, blacks among the growing ranks of contract pork producers (Wing et al. 1996; Heath 1998; Land Loss Fund, n.d.), and suggests that not only are minority communities suffering greater environmental risks from corporate swine production, but that within those counties, minority households are also not sharing in the localized economic benefits.

While demonstrating racist intent in such outcomes is a crucial issue in models of "pure discrimination" and in civil litigation under current interpretations of civil rights law, the presence of environmental injustice, as we have argued, need not depend on the demonstration of intentional discrimination. Rather, the continuing effects of historic discrimination and the stratification of adverse impacts, regardless of intent, are core environmental justice issues, whether or not they lend themselves to litigation in the current political climate. In other words, the methodological individualism inherent in "judicial" approaches emphasizing racist intent deflects analytical attention away from structural socio-economic stratification processes. Following Downey (1998) and

Stretsky and Hogan (1998), we take an institutional view of discrimination. From that perspective, this analysis provides strong evidence of discriminatory outcomes by race, and shows that those impacts intensified during the period of most rapid industry growth and concentration between 1992 and 1997.

Poverty and Region

The interpretation of poverty is complicated by regionally specific patterns of uneven development. Over the period examined here, low-income counties outside of eastern North Carolina have seen their hog populations decrease, while the opposite is true in the East. The negative relationship between poverty and hog populations outside of eastern North Carolina is attributable to two broad phenomena. First, poverty rates in the mountains are higher than in the Piedmont, but the mountains have no history of significant commercial hog production and are geographically unsuitable because of topography and distance to slaughtering facilities and supply sources which are now all in eastern North Carolina. Secondly, in the Piedmont highly urbanized counties, which are less suitable for hog production, also have higher rates of poverty than rural or suburban areas. Generally, we found no effect of poverty statewide and failing to take account of regional variations would have missed an important dynamic in understanding patterns of environmental inequality in this case. Our results make clear that the relationship between poverty and swine waste concentration is regionally mediated.

At all four points in the cross-sectional analysis (Table 3) and increasingly over the 15-year period (Table 4), the poorest counties in the state's most economically distressed, underdeveloped and most politically marginalized region have shouldered larger concentrations of swine waste. Some recent commentators have argued that, if empirical environmental justice research included adequate controls for regional variations in economic development, urbanization, and other market factors thought to predict the spatial distribution of polluting industries, that the relationship between environmental justice variables and the intensification of environmental externalities would be mitigated if not eliminated altogether (Been 1994). Our findings here offer no support for that argu-

ment. In fact, our findings beg questions about how regionally specific paths of production became established in the first place. Better understandings of the causal mechanisms shaping the distribution of environmental hazards need to integrate qualitative historical analyses with the kinds of statistical analysis presented here. The structural origins of environmental injustice direct analytic attention toward the intersection of political-economy, historic and institutional discrimination, the uneven distribution of risks and rewards associated with contemporary patterns of economic development. Similarly, the conflicts surrounding persistent environmental injustices raise enduring questions about differential access to power by class, race and gender, as well as the often contradictory role of the state as different levels of government and agencies respond to different constituencies and work simultaneously to both facilitate environmental injustice and mitigate its consequences.

Mobilization Matters

Our findings also highlight the importance of political capacity in two ways and suggest that it be more consistently integrated into environmental justice research. First, a careful examination of the historical political economy of North Carolina would likely offer compelling evidence to explain the regionally specific patterns of environmental inequality presented here. Specifically such analyses could explain why eastern North Carolina came to be politically marginalized and how its powerlessness relative to the Piedmont region has led to contemporary patterns of underdevelopment and economic stress which erode its current political capacity.

Second, along with regional disparities, our results direct more analytic attention to localized mobilization capacity. Local political capacity is a strong negative predictor of hog population size across all four periods of our cross-sectional analysis, as well as a strong predictor of hog population decrease in the longitudinal analysis. The importance of local mobilization capacity on this issue is exemplified by the cases of Halifax and Edgecombe Counties. In the early 1990s, during a time when the state had made large hog operations exempt from local zoning authority, Halifax County made itself a path of more

resistance by passing county health ordinances to protect residents from industry externalities and effectively curtail hog population growth in the county. In 1995, a coalition of local officials, concerned citizens, and grassroots environmental organizations emerged in Edgecombe County to effectively block Iowa Beef Packers, Inc.'s plan to construct a large swine processing facility capable of slaughtering about 22,000 head per day. This facility would have increased the state's pork slaughtering capacity by more than half and led to a commensurate increase in the total hog population. It would also have led to an intensified hog concentration in that part of the coastal plain. Both of these local efforts were accomplished in large part by coalitions of local officials, strong grassroots advocacy organizations, and concerned citizens. Few other counties in the region had such political resources in place prior to the influx of CAFO-style hog operations.

Conclusion

The research presented here has examined the socio-economic and political attributes of communities within one of the world's leading pork production zones and their association with patterns of swine waste concentration over a 15-year period of pork industry expansion and restructuring. We find evidence that during this period of industry restructuring and consolidation, the adverse impacts of swine waste have followed a path of less political resistance with industry locating in minority and low-income communities of North Carolina's poorest and most politically marginalized region. Currently, one multi-national firm controls pork production and processing throughout North Carolina and is reaping enormous profits, which critics argue is possible in part because the industry has been able to shift the social and environmental costs of swine waste disposal onto the rural population. The research presented here provides strong evidence that politically marginalized, poor, and minority citizens are shouldering the bulk of these costs, even as industry profits are displaced to corporate shareholders or used to capitalize the acquisition of domestic and foreign competitors. For social scientists interested in the growing linkages between industrial restructuring, regional political

economy, and environmental injustice, the escalating conflicts surrounding "assembly-line swine" offer an instructive exemplar for further research.

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End Notes

¹ County-level environmental justice analyses have been criticized for aggregation problems inherent in the large areas covered by counties (especially in the West) and the statistical assumption that environmental risks are evenly distributed across the county. The major limitation of county-level analysis is aggregation bias or its inability to statistically account for varying levels of exposure within each county such as residential proximity to a CAFO, downwind/downstream location, or the extent to which residences along county borders may experience increased or decreased levels of exposure from neighboring counties. In the case of North Carolina, this is less a problem because on average North Carolina's 100 counties (487 sq. mi.) are less than half the size of those in the other 49 states (1,145 sq. mi.) (Statistical Abstract of the United States, 1998). Overcoming this limitation would require, at a minimum, data on the precise location and size of each CAFO over the entire period covered by this analysis, as well as geographical data on downstream dispersions related to wind patterns and to-

pography. Such data are not available. Data on the post-moratorium location of swine CAFOs have only recently been collected by state regulators. For a cross-sectional analysis of the demographic composition of census blocks that use GIS data on post-moratorium CAFO locations that come to largely compatible conclusions as the analysis presented here, see Wing et al. 2000.

² The total number of swine in the state during an entire year would, of course, be substantially higher because, roughly speaking it takes six months to raise a hog from "farrow" to "finish," or more colloquially, from birth to bacon. We use the more common and conservative "daily average" herd size which estimates the number of hogs currently alive on any given day rather than the total number of hogs that pass through a county annually. An alternative measure would be the "steady state live weight" (SSLW) for each county. The state Department of Water Quality calculates this by considering the number of hogs at differing stages of development—farrow/birth to wean, wean to feeder, feeder to finish, boars and gilts, and breeding sows—in each county and the average weight of each type of hog. While SSLW might be a more appropriate measure of hog industry externalities in analyses of smaller spatial units, we chose the number of hogs because it is a more intuitive conceptualization that does not differ substantially from SSLW at the county level.

³ Two counties, Duplin and Sampson, are outliers in terms of hog population. Their proportions of nonwhite and poor residents also are approximately 1.5 times the state average.

⁴ This measure was calculated by subtracting the percent white from 100, thus it includes Native Americans who comprise the single largest proportion of residents in Robeson County, NC's sixth largest swine producer in 1997. It also includes the North Carolina's rapidly growing Latino/a population which was still quite small in 1990, much less 1980.

⁵ Our 1980 measure of local political capacity is the mean of each county's Z score for percent registered to vote in 1980 and the percent with college degree in 1980. The 1990 measure uses percent regis-

tered to vote in 1992 and percent college educated in 1990.

⁶ Table 1 presented mean scores for unemployment and annual wages. The measures used in the regressions were derived from the mean of the Z scores for annual wages and employment rates so that a lower score corresponds with a more favorable business climate in terms of lower wages and higher unemployment.

⁷ For the results presented in Tables 2 and 3, the variables used to predict the 1982 and 1987 hog populations were measured in 1980, while 1990 measures were used to predict the hog population in 1992 and 1997. In analyses, not presented here, we used 1980 measures to predict the 1992 and 1997 hog populations and found a pattern of results comparable, substantively and statistically, to those in Tables 2 and 3

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Hookerton, North Carolina: A Small Community Rescued by Duckweed?

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The Hookerton Story

Hookerton, nestled on the high, southern bank of Contentnea Creek in Greene County is a metaphor for small, older towns in Eastern North Carolina. Main Street, punctuated by two blinking traffic lights, is lined with shuttered, boarded buildings and well-arbores, small wood and brick homes that date to the 30s, 40s and 50s. There's a functioning gas/service station, a branch bank, a tiny post office, "city hall" and a "latino-flavored" convenience store. The latter facility, crafted from an old, well-worn gas station, is now the only place in town selling food – or anything, for that matter. That it is "latino" in its emphasis is also a sign of the times. The barber shops, hardware stores, feed stores, grocery stores, appliance stores, furniture store, fish shop, butchers shop, department store, shoe store, bakery, cinema, café, hotel and restaurants are long gone – all victims of the "scale economies" that have given rise to the regional "dollar" strip retail malls, the Walmarts and K-Marts, regional "super" grocery stores, Pizza Huts, McDonalds' and BurgerKings (Creech, 1979; personal communication with Hookerton residents, 2001). The only visible reminder of the railway line are the trestle remnants that still show when Contentnea Creek is running low. Tragically, gone too are the doctors, dentists, clinics and the public schools. Indeed, it was the loss of Hookerton High School – a victim of Snow Hill (county seat) inspired "County Consolidation" – that signaled the beginning of Hookerton's long decline (personal communication with Hookerton residents, 2001).

Hookerton has shrunk to half the size it was during its heyday of the 40s, 50s and 60s, but most of the old names are still there: the Joneses,

McLawhorns, Hills, Wootens, Albrittons, Creeches, Heads, Suggs, Murphys, Beamons, Barrows, Dawsons, Ginns, Turnages, Hardys and Moyes. The young folk simply keep drifting away. Some have migrated to the countless "double wides" artlessly crammed into the numerous "trailer" clusters or pseudo "townlets" that now litter Greene County's back roads, but most have moved "up and out" to Greenville, Raleigh, Charlotte and beyond. As the old folks say, "There's nothing left for them here in Hookerton" (personal communication with Hookerton residents, 2001).

In recent years, like many small North Carolina communities, Hookerton has seen a precipitous decline in its economic and population base. It is now only just hanging on from the marginal revenues derived from its three aged town-owned utilities: water supply, wastewater collection and treatment; and electric power supply. The town park and tennis court, cracked and sprouting weeds, have fallen into irreparable disrepair. The creaking community center is showing its age. The venerable, "non-standard" electric distribution utility, described by a regional CP&L (the dominant regional electric company) engineer as having "less than zero value," requires a complete "make-over" (personal communication with CP&L engineer, Kinston, NC, 2001). The town's water supply needs new wells, pumps, meters and distribution lines. Its sewage collector network has collapsed in spots, needs new lift pumps, requires new bridge supports and is heavily infiltrated by rainwater. Finally, Hookerton's ancient three-cell facultative lagoon wastewater treatment system is unable to meet even relaxed "30-30"¹ discharge standards (NC Environmental Management Commission, 1998). It is this

latter “non-compliance” which has finally served to rouse the town from its seemingly inexorable slide towards the eventual loss of its municipal charter – a destination already apparently reached by its Greene county twin, Walstonberg, where a petition to revoke the town’s charter is now being circulated among the town residents.

Initially, Hookerton’s inability to meet its permitted “30-30” water quality discharge standard resulted in a succession of “fixes” prescribed by cognizant DENR (Department of Environment and Natural Resources) compliance engineers based in the “Little” Washington regional office. These suggestions ranged from chlorine application (pouring Sodium Hypochlorite or common bleach into the town’s third lagoon) to intermittent discharge and finally extended aeration (personal communication Hookerton WWT manager, 2000). Nothing worked. Hookerton was finally urged to seek a “new system.” After six years of inaction by the town, urging turned to “mandate,” with imposition of a Special Order of Consent (SOC) by the North Carolina Environmental Management Commission (EMC). The SOC mandated construction, within three years, of a new system that would bring the town into compliance with its existing discharge permit. In the interim, the town’s discharge standards were relaxed, but Hookerton was also strictly prohibited from engaging in any new “development.” Failure to comply with both the terms and timetable dictated by the SOC would subject the town to a maximum possible daily fine of \$2,000 (NC Environmental Management Commission, 1998).

With its SOC, Hookerton reluctantly gained membership to a notorious group of approximately 120 North Carolina communities that are now operating under a “development moratorium.” As with Hookerton, all these communities – including county seat, Snow Hill and nearby Kinston, home to the Global Transpark – are prevented from providing wastewater treatment services to any new clients. This has the practical effect of freezing all commercial and domestic real estate development in each SOC affected community (NC Environmental Management Commission, 2001).

Having no option but to follow the dictates of the SOC, Hookerton instructed the local engineering

company then handling its water and wastewater engineering needs, to develop plans for a new system. The firm recommended that Hookerton should subscribe to a portion of the new wastewater treatment capacity then being planned for construction in nearby Snow Hill. Hookerton would avail of that capacity through a “force main” pipeline designed to pump up to 60,000 gallons of raw wastewater up Contentnea Creek to the new Snow Hill facility.² The Snow Hill “regional” plant would also, under the engineering firm’s proposal, accommodate some demand from housing developments located outside the Snow Hill municipal perimeter in adjacent areas of Greene County (Town of Hookerton, 1999b).

After reviewing the regional facility proposal, it became evident to the Hookerton mayor and Board of Commissioners that the town was being asked to subsidize buffer surplus wastewater treatment capacity which would, in the future, serve only the needs of Snow Hill and its Greene County “suburbs” (personal communication with Hookerton Mayor, 2000). The fixed, 60,000 GPD (gallons per day) capacity of the proposed Hookerton-Snow Hill force main would effectively prohibit Hookerton from benefitting from any of the proposed regional system’s surplus capacity. The town commissioners also realized that, by committing to off-site treatment, Hookerton would lose its existing wastewater treatment permit – and with it, any ability to control its own destiny with respect to future growth. The Hookerton Board of Commissioners after much internal debate reached the conclusion that subscription by the town to the proposed regional wastewater treatment facility would have the effect of absolutely inhibiting any future growth for the town. This was, for the commissioners, a sobering realization, because they had also come to understand that the only way to salvage the town from its present steadily declining circumstance was to grow – to grow to a size that would transcend some of the scale economy thresholds now imposed upon them. They also understood that the only way the town could grow would be to offer potential new clients – both households and businesses – additional wastewater treatment capacity (personal communication with Hookerton Mayor, 2000). Hookerton chose, therefore, to explore alternative systems that would enable the town to move beyond its current

(and proposed future) permitted wastewater treatment capacity of 60,000 GPD – options that would allow the town continued control over its future growth.

After considerable internal debate, and under the pressure of regional pipeline system stakeholders, the Hookerton Commissioners finally committed themselves to the regional system, despite its disadvantages. This was agreed to with one caveat: Hookerton would only agree to participate in the regional pipeline project if all costs associated with construction of the project were covered under a grant from the NC State Revolving Loan and Grants Fund. The town was privately assured by its engineering firm and DENR cognizant engineers that prospects for receipt of a full grant were excellent (personal communication with Hookerton Mayor, 2000).

In an inspired move, designed originally to mollify proponents of future growth and advocates of the selected alternative system, the Hookerton commissioners also agreed to a “parallel track” approach wherein the town would also apply for funding for that system from the NC Clean Water Management Trust Fund. Again, with a single, though somewhat more restrictive caveat: Hookerton would spend no resources whatsoever on the proposed alternative project – whether in application or implementation (personal communication with Hookerton Mayor, 2000).

Hookerton’s “pipeline” proposal to the NC State Revolving Loan and Grants Fund was ultimately rejected – in two successive funding cycles. Reviewers deemed the projected \$1.2+ million dollar project as providing “too little bang for the buck.” Ironically, the alternative project – a proposed duckweed-based nutrient removal and wastewater polishing system – was approved for a \$0.78 million grant from the NC Clean Water Management Trust Fund (Town of Hookerton, 1999a)³.

Following a 12-month wait for DENR construction approval of its new duckweed wastewater treatment plant, Hookerton is now engaged in negotiating a construction and O&M agreement that should see the new plant fully operational by the summer of 2002. System design engineers have committed that Hookerton will, at that time, deliver the highest level

of municipal wastewater treatment of any community in the United States.

“The Duckweed Project,” as the alternative project has now come to be known, represents a radical departure from conventional wastewater treatment approaches now being prescribed for small communities in North Carolina. The project promises four unique innovations: (a) treatment of wastewater to a drinking water standard – namely to a much higher level than is required by law; (b) complete recycling of that treated effluent; (c) incremental, marginal need-based increase in future system capacity; and (d) a positive cash return on the “production and sale” of harvested duckweed – the new system’s biological nutrient reduction agent (Town of Hookerton, 1999b).

Building on the potential for growth offered by the town’s new wastewater treatment system, discussions are already engaged between the town, proximate landowners and outside developers and financiers that promise development of the first Greene County golf course “community” on the Hookerton periphery. The 300 “luxury homes,” Lenoir Community College satellite campus and Greene County industrial park that are planned for construction within the community should be more than sufficient to reverse Hookerton’s long decline and inject new commerce and vitality back into the town. Hookerton is clearly turning the corner (personal communication with Hookerton residents, 2001; personal communication with Hookerton Mayor, 2001).

Following a brief primer on wastewater treatment, and description of the “duckweed system” now being installed at Hookerton, the balance of this article is devoted to examining the effects these innovations are expected to have on Hookerton, as a town and community, and to discussing the implications of Hookerton’s turnaround for other small communities throughout North Carolina.

A Wastewater Treatment Primer

Before embarking on a specific description of the Duckweed System, it is instructive to gain a basic understanding of wastewater treatment.

The simple objective of every municipal wastewater treatment system is to render the final, discharged effluent more pure than when it entered the facility,

and to do so in a manner that meets minimal standards imposed by state and national regulatory authorities. The treatment function typically contains three basic elements: (a) removing solids, (b) removing chemicals (principally nutrients) and dissolved solids and, finally, (c) killing pathogens. Every wastewater treatment plant will, in some fashion, attempt to achieve the first two. Formal attention to the latter, killing pathogens, is also rapidly becoming an essential element in every modern system. Critical ancillary tasks include “dealing” with the solids, once removed, and the treated wastewater once it has passed through the system.

The entire spectrum of wastewater treatment “approaches” can be divided between “passive” and “active” systems – with the former occupying relatively large amounts of land and using little energy and the converse characterizing the latter. Active systems are, in general, capable of delivering a marginally higher level of treatment than passive systems. The basic rule of thumb had always been to employ passive systems in circumstances where land values are low and capital constrained; and active systems where land values are high and financing readily available. With minor exceptions, however, this is no longer the case. In more affluent societies able to indulge higher levels of concern for the environment, rapidly tightening effluent standards are now rendering most passive systems infeasible – systems such as, for instance, Hookerton’s aging facultative lagoon complex.

Removing solids, in both active and passive systems involves two stages. In the first stage solids carried in the influent wastewater must be removed from the waste stream. Solid objects having high integrity are easily removed through a simple screening device. Those which break down to fine constituents must, in some fashion, be precipitated from the waste stream. Most passive systems employ a large, “primary” lagoon where influent solids gradually sediment on the bottom, where they subsequently remain, slowly decaying, for the active life of the system. Active systems, on the other hand, employ chambers of various configurations specifically designed to optimize influent solids settling and concentration for subsequent removal.

Second stage solids removal involves purging biological nutrient uptake agents. In truly passive

systems this means precipitation of phytoplankton – principally algal species. This painstakingly slow process is achieved by extended hydraulic detention in successive lagoons wherein increasingly nutrient-deprived algae gradually expire and slowly settle to the lagoon bottom. Second stage solids removal in active systems, on the other hand, involves extraction of aerobic bacteria species. This is a somewhat more efficient process than removing algae, because aerobic bacteria expire quickly when deprived of both nutrients and oxygen. The whole process can be achieved with detention times of less than 24 hours in a deep quiescent, usually circular chamber called a clarifier.

Nutrient and dissolved solids removal in both active and passive systems is, with minor exception, achieved by promoting the growth of a select, targeted family of organisms. So called “activated sludge” systems employ a wide range of aerobic bacteria to uptake nutrients. Most lagoon systems achieve the same function with algae. Occasionally, lagoon systems have also been adapted to promote growth of macrophytes such as water hyacinth and duckweed species. Constructed wetlands, the modern passive system successor to lagoons, take a more eclectic approach to nutrient uptake, employing a wide variety of rooted and floating macrophytes in addition to zoo- and phytoplankton. As we have already described (above), algae, bacteria and other biological nutrient removal agents must subsequently themselves be removed from (or separated from) the wastewater to effect treatment. In the case of truly passive lagoon and wetland systems, treatment efficiencies are degraded by ongoing release by decaying organisms of nutrients back into the wastewater stream.

Sterilization of treated effluent employs one, or a combination of three systems: traditional chlorination, ozone contact or ultraviolet irradiation. Use of chlorine is increasingly frowned upon because it creates trihalomethanes, a family of potent carcinogens, from residual organic compounds still present in the final effluent. Effectiveness of ultraviolet treatment is a function of effluent clarity. With increasingly higher levels of treatment (and hence discharge effluent clarity) now being achieved, it is rapidly becoming the system of choice. Employed with great success sterilizing swimming pool water, ozone is also finding applications in a significant number of large

scale commercial systems – many in combination with ultraviolet irradiation.

Dealing with the vast quantities of bacterial sludge produced by active, aerobic systems, has always been one of the most difficult and costly elements of modern, mechanical wastewater treatment. Despite the theoretical potential for converting sludge to a highly remunerative organic soil enhancer, no large wastewater treatment facility has ever succeeded in covering a significant portion of its O&M cost (not to mention capital costs) through commercial sale of such products. “Milorganite” a fertilizer product of Milwaukee’s municipal wastewater treatment plants has garnered great conceptual acclaim from environmental circles throughout the United States, but never the widespread consumer acceptance necessary to make it a true commercial success.

Duckweed Wastewater Treatment

The “alternative” duckweed wastewater treatment system being installed by the town of Hookerton falls somewhere in the middle of the “active – passive” continuum. It occupies significantly less space than a typical facultative lagoon system, but also uses much less energy than an activated sludge plant. As with any wastewater treatment plant, duckweed systems must deal with influent solids. The Hookerton system will simply “leave in place” the existing primary lagoon which is now effectively serving to sediment influent solids. Duckweed systems constructed in other communities that are unable to “build on” existing lagoon complexes will typically employ aggressive solids separation and digestion approaches now favored by the aquaculture industry. These employ a number of centrifugal devices arrayed in series to remove solids from the main wastewater stream. Those solids are subsequently treated in a 2-phase (thermophilic/mesophilic) continuous flow-through anaerobic digester which reduces their volume by 90%-95% while also “recovering” their inherent nutrient constituents for subsequent “recycling” through harvested duckweed plants.

The “guts” of a duckweed wastewater treatment system is the duckweed system itself: an array of greenhoused bioreactors growing a continuously harvested duckweed crop (see figures 1. and 2.). This

biological nutrient removal system is analogous to the bacteria in activated sludge systems and the algae in passive lagoon systems. It holds significant technical advantages over both. Duckweed can remove nutrients, metals and both organic and inorganic compounds from water with higher efficiency than either bacterial or algal systems, and, unlike either of those two systems, it is trivial to remove, or “harvest” from the wastewater once it has performed its treatment function. A further advantage of duckweed is that it is highly nutritious and therefore valuable as an additive in livestock and fish feeds (Skillicorn, 1993).

In combination, these characteristics give duckweed an overwhelming advantage over all conventional wastewater treatment systems now in operation. It is instructive to put some numbers to that advantage. With respect to nutrient removal, continuously harvested duckweed systems have been shown reliably to bring combined ammonia and nitrate nitrogen to below 0.2 mg/l in treated discharge (Alaerts, 1996). This is approximately one thirtieth the level achieved by the average modern activated sludge plant (6+ mg/l combined nitrate and ammonia nitrogen), and one tenth the level expected of a state-of-the-art SBR (Sequencing Batch Reactor) system⁴ (2+ mg/l combined ammonia and nitrate nitrogen). Relative performance for difficult-to-remove phosphorus, heavy metals and toxic organic and inorganic compounds is even better, with typical advantages over SBR systems exceeding ten to one.

The ease with which floating duckweed plants can be removed from water gives duckweed systems a significant capital and O&M cost advantage over all bacterial system (see figure 3). In particular, it obviates the need for expensive clarification and sludge concentration devices and processes. Continuously skimming duckweed from the surface of a “duckweed bioreactor” is a trivial task. Having been removed from the waste stream, duckweed, a living, odor-free leafed macrophyte is then amenable to easier handling and subsequent “processing” than is the malodorous dead bacterial sludge product of an activated sludge wastewater treatment plant.

Harvested wet, duckweed plants contain approximately the same moisture and nutritional value as whole milk. Dry weight protein content of “well fed”



Figure 1. Greene County, North Carolina duckweed greenhouse showing inflated plastic covering and excavated earthen tank.

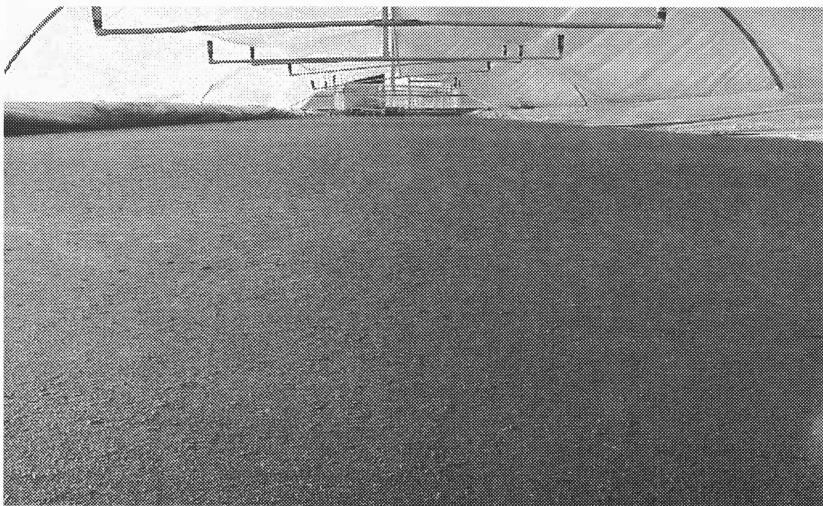


Figure 2. Greene County, North Carolina duckweed greenhouse showing interior configuration and duckweed “mat” cover.

duckweed plants can exceed 45% (Skillicorn, 1993). Their protein, which is high in "animal" amino acids methionine and lysine, has significantly higher market value than that produced by soybeans. Duckweed contains significantly more mineral and vitamin value than either milk or soybeans. Vitamin A and beta carotene levels, for example, exceed that of any other known plant species. Duckweed plants also have high levels of folic acid and the valuable feed industry pigment xanthophyll.

Recent developments pioneered at NC State University have also shown duckweeds to be particularly amenable to genetic engineering. Scientists have demonstrated that a wider range of human, animal and plant proteins can be "introduced" into duckweed through conventional recombinant DNA techniques than are accommodated by either *e-coli* bacteria or yeast, today's common "engines" for production of genetically engineered proteins. This makes very real the prospect of duckweed-based wastewater treatment plants serving as "factories" to produce, in particular, a range of valuable industrial enzymes such as xylanase, laccase and cellulase. The value of duckweed's ease of engineering is further enhanced by the plant's favored means of reproduction – cloning. Once "engineered," an enzyme producing duckweed variety can continue to be cloned indefinitely (Personal communication, Biolex executives, 2001).

Figure 1. depicts a typical duckweed "greenhouse" configuration. The interior "bioreactor" comprises a simple, lined tank allowing maintenance of a 2.5' deep water column. A typical tank configuration is 100' x 17' x 3'. The 2-ply plastic greenhouse borrows its design from systems now employed in the surrounding counties to produce tobacco seedlings. Side curtains are not employed in order to maximize control over internal temperatures. The Hookerton design features a dual parallel tank configuration under a single 100 x 35' greenhouse (Town of Hookerton, 2001a). While earthen tank construction is preferred, concrete construction can be employed in circumstances where available space is constrained. A single 1000 watt fan provides adequate system ventilation to ensure crop maintenance within a desired temperature range during summer months.

Figure 2. depicts a typical duckweed greenhouse interior. It is noteworthy that surface coverage by the

duckweed "mat" is comprehensive. This ensures complete blockage of light penetration into the water column and effective inhibition of phytoplankton growth which, in turn, minimizes presence of suspended solids in treated discharged effluent. Spray nozzles employ treated, recycled wastewater to effect a variety of specific "mat" maintenance functions.

Figure 3. depicts a duckweed harvester employing a simple "capture" method to remove a portion of the floating duckweed mat from the bioreactor. The harvester additionally serves to redistribute the mat over the bioreactor surface on the return leg. Fully automated hydraulic harvesting systems will be deployed in the new Hookerton facility (Town of Hookerton, 2001a).

Figure 4. depicts the clarified, treated effluent output from a duckweed-based swine waste treatment facility based in Greene County, North Carolina. Discharge quality for the facility exceeded, by a significant margin, the strictest standards imposed on treatment of municipal wastewater in North Carolina.

Figures 5. depicts the three main duckweed genera, *Spirodela*, or giant duckweed, *Lemna*, or common duckweed, and *Wolffia*, the smallest known flowering plant. *Spirodela* species, averaging 0.5 cms in diameter, are characterized by a "tuft" of small roots emanating from their ventral surfaces. *Lemna* species, averaging approximately half the diameter of *Spirodela* species, are characterized by a single root. Tiny *Wolffia* species have no roots whatsoever and effect a rotund shape, as opposed to both *Lemna* and *Spirodela* which have relatively flat fronds. Despite their ability to produce fruit and seeds, it is duckweeds' ability to reproduce vegetatively by cloning which contributes most to their remarkable reproduction and growth rates. Each "mother" frond can produce between seven and ten daughter fronds during its life cycle.

The Implications of Hookerton's Adoption of Duckweed?

Two questions are posed: "What is the implication to Hookerton of its commitment to duckweed-based wastewater treatment?" and, by extension, "What significance does this hold for similar communities in North Carolina and across the South?" Before delving into these questions, it is useful to gain some understanding of the wastewater treatment

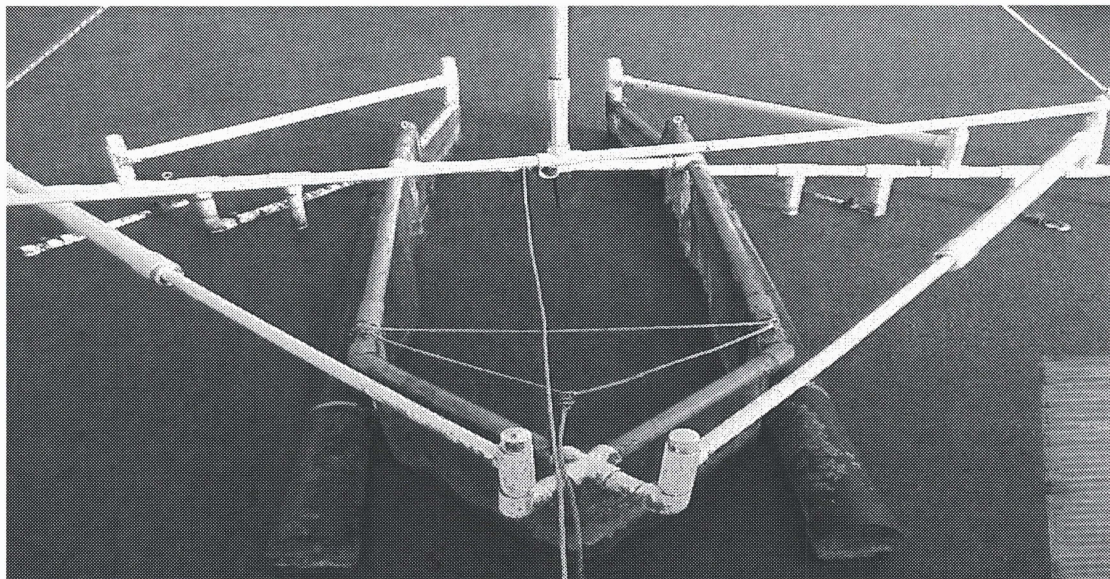


Figure 3. Duckweed “capture” harvester.



Figure 4. Greene County, North Carolina showing treated swine waste being discharged from a duckweed greenhouse.

equation in North Carolina. Indeed, it is Hookerton's need to react to that equation which now dominates the town's current circumstance and future prospects. Hookerton's situation is not unique in that respect. During the coming decade every small town in North Carolina, indeed, across the nation, will be faced with the same issues that Hookerton is now confronting.

North Carolina state environmental authorities have estimated that it will cost approximately \$10 billion during the coming decade to meet the state's requirements to upgrade water, sewer and wastewater treatment requirements (personal communication, NC Rural Center, 2001). Of this requirement, the major share will be required to bring aging wastewater treatment plants into compliance with tightening state standards. The vast majority of old systems are deployed in small communities such as Hookerton that have experienced little growth in recent years.

As a general rule of thumb, scale economies dictate that acquisition of "conventional" technology able to deliver advanced tertiary effluent such as is already required for Neuse River basin communities will cost small communities more than twice what larger (25,000+ populations) towns must pay for the same treatment system performance (See figure 6.). Small communities lacking an industrial tax base, many already burdened with extraordinary "Electricities debt",⁵ either cannot borrow or must pay premium rates if allowed to do so (See figure 7.). Further, these same communities cannot deliver on the critical "bang-for-buck" criterion applied by the state revolving loan and grants fund when its limited pool of capital resources is allocated.

It is instructive to examine Hookerton's specific circumstance. Hookerton is currently saddled with a

\$4.967 million dollar bond debt for its 0.155% share of the nuclear power plant capacity it bought collectively with its North Carolina Eastern Municipal Power Agency partners (personal communication with Electricities executives, 2001). Paying back this debt over 30 years at a 6% rate of interest represents a \$147 monthly burden to each of the town's 205 families – that is *before* they even pay their electricity usage bill. The town's entire electric distribution infrastructure is in need of replacement.

Doing so would place a similar monthly burden on each family. If Hookerton wished to develop a conventional wastewater treatment system sufficient to attract 300 luxury homes, a golf course and country club, a satellite college campus and a new industrial park, it would need to double its existing capacity. This would immediately subject the town to the new Neuse River advanced tertiary treatment standards. Constructing a new 120,000

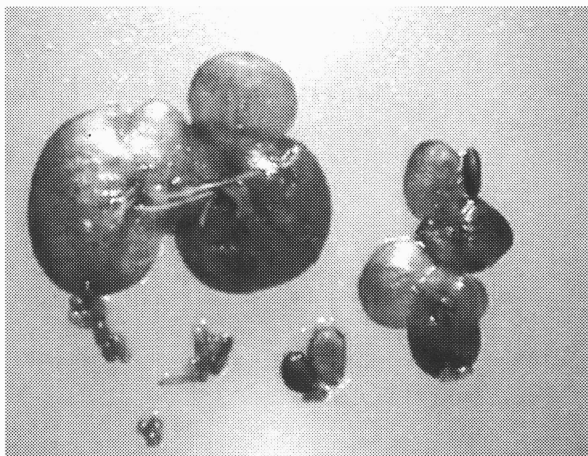


Figure 5. Three main duckweed genera, shown from the bottom: *Wolffia* (smallest), *Lemna* (medium) and *Spirodela* (largest).

GPD advanced tertiary treatment system would cost the town an expected \$30 per gallon of installed capacity, or \$3.6 million, and impose a capital cost burden of approximately \$36 per month on each of the town's 500 (200 current and 300 new) homes – *before* operations and maintenance costs are figured in. Given its inability to qualify for previous grants from the DENR Revolving Loan and Grants Fund, the town would be unlikely to obtain grant funding. Borrowing the funds when it already has almost \$5 million in existing nuclear power plant debt would certainly be problematic. Hookerton would clearly have great difficulty developing a favorable circumstance which would allow it to grow. Indeed, even were it able to obtain the financing it sought, the significantly higher rates the town must already charge for the electricity it delivers, combined with higher than average rates for

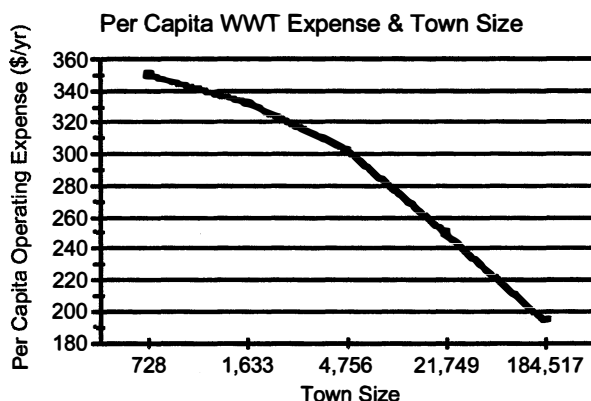


Figure 6. Source: 2000 Budgets for Pink Hill, Snow Hill, Mt. Olive, Goldsboro, Cary and Raleigh, as obtained in 2001 from the NC Treasury Department.

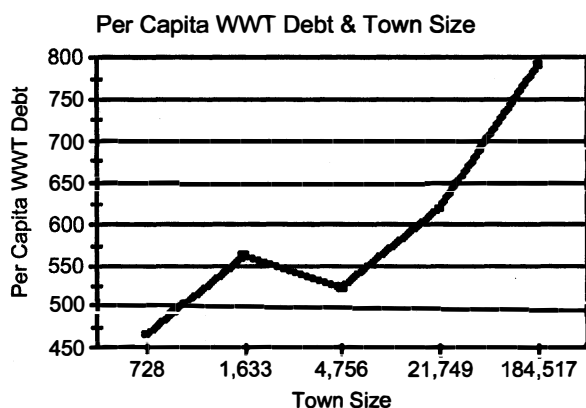


Figure 7. Source: 2000 Budgets for Pink Hill, Snow Hill, Mt. Olive, Goldsboro, Cary and Raleigh, as obtained in 2001 from the NC Treasury Department.

water and wastewater would certainly deter most industrial clients and also probably most potential new residents.

The duckweed system Hookerton is now installing will cost the town nothing. Most of the new system capital costs are being covered by a grant from the NC Clean Water Management Trust Fund under its program to support "innovation" in wastewater treatment throughout North Carolina (Town of Hookerton, 1999a). The balance of capital costs will

be invested by the company that will both build and operate the new system (personal communications, Proterra executives, 2001). Despite the town having just constructed a wastewater treatment plant capable of delivering the highest effluent discharge quality in the state, there will be no impact whatsoever on Hookerton's existing 205 families. Assuming the same development scenario outlined above, doubling Hookerton's duckweed wastewater treatment capacity to 120,000 GPD would, at \$8.00 per additional in-

stalled gallon of capacity, cost approximately \$480,000. This would impose a capital cost burden of \$5 per family on the town's 205 current and 300 new households, raising monthly wastewater treatment costs to around \$20 per family. In an era of sharply rising water and wastewater fees these rates should remain among the lowest in the state. While electricity fees will continue to remain a significant liability for Hookerton, particularly with potential industrial clients, the town is considering "reaching out" with its new "expandable" wastewater treatment utility to provide services to neighboring communities and housing clusters. Revenues derived from provision of such services could help to defray the town's high electricity rates.

Going one step further, Hookerton is seeking to negotiate a "profit sharing" arrangement with its wastewater contractor wherein the town will receive a percentage of profits from the sale of duckweed and duckweed derived products produced at the Hookerton facility. By offering the management company a remunerative "partnership" in its municipal utility, it is also providing a clear incentive for that company to drive the process of bringing in new clients – both "in-town" and remote clients. With the management company aggressively marketing its new, low cost utility, it is not unlikely that Hookerton may

soon begin providing wastewater treatment services to new clients located in the nearby Global Transpark as well as in rural communities and housing clusters in Greene County. It is even conceivable that the town can provide truly "remote" wastewater treatment services to both industrial and residential clients located in the growing fringes of neighboring cities like Kinston, Goldsboro, Greenville and Wilson. This would be achieved by building remote treatment facilities constructed in or proximate to those communities.

If Hookerton is able to breakthrough and achieve significant positive growth, it will serve as a powerful model for the thousands of small towns and communities that now share a similar fate. Perhaps more significantly, it will serve to arrest – possibly even reverse – the continued migration of people from those communities to the state's urban/suburban growth poles. If this can be made to happen, the impact on the state budget will be profound. A comparative examination of state subsidies versus community size (See figure 8.), suggests that it costs the state more than twice as much to support a person in large cities such as Raleigh and Charlotte as it does in Hookerton and like communities.

Duckweed wastewater treatment systems, by lowering the cost of wastewater treatment, increasing the

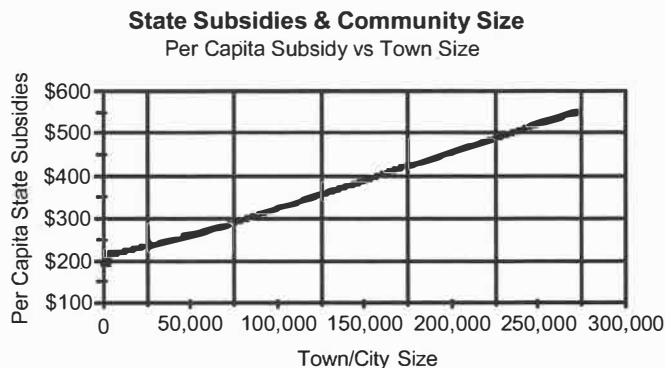


Figure 8. Source: 2000 Budgets for Pink Hill, Snow Hill, Mt. Olive, Goldsboro, Cary and Raleigh, as obtained in 2001 from the NC Treasury Department.

quality of treated effluent and generating revenues from duckweed harvested from those systems, can serve as an engine by which America's small communities may reverse their contemporary history of misfortune. Adoption of duckweed systems and provision of inexpensive wastewater treatment capacity can serve again to make America's small communities attractive places in which to live and to work.

End Notes

- 1 30 mg/l BOD (Biochemical Oxygen Demand), a measure of organic content; and 30 mg/l TSS (Total Suspended Solids), a measure of turbidity, is a standard treatment level prescribed for municipal wastewater treatment plants throughout the world. Recently issued NPDES discharge permits in North Carolina are mandating standards which have the effect of requiring both BOD and TSS reduction to below 5 mg/l, respectively.
- 2 Hookerton is presently permitted to treat 60,000 gallons of wastewater per day.
3. Author Paul Skillicorn is an environmental engineer with expertise in duckweed-based wastewater treatment. He has volunteered his assistance to the town of Hookerton in planning and designing the town's new duckweed wastewater treatment plant.
- 4 SBR systems employ sophisticated "sequenced" aerobic and anoxic reactions in a batch process to achieve exceptionally high treatment efficiencies.
5. Under "Electricities" numerous North Carolina Municipalities were induced to directly acquire ownership in two nuclear power plants then being constructed by CP&L and Duke Power.
6. Having a low installed capacity cost, and amenable to incremental expansion, duckweed systems can "expand" as necessary to meet specific customer requirements.

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The North Carolina State Climate Program 25th Anniversary

Peter J Robinson,
Coordinator, NC State Climate Program
Department of Geography

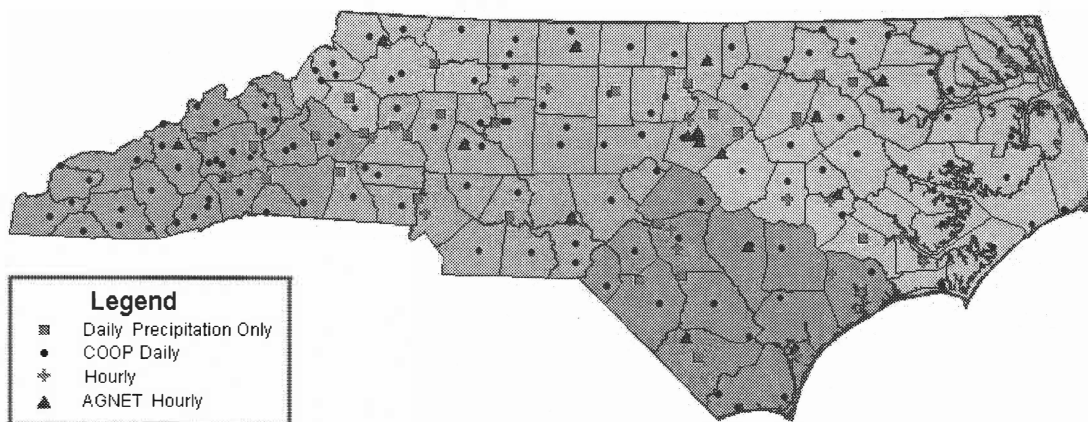
Twenty-five years ago the State Climate Office (SCO) of North Carolina was created. The mission was to provide climate information and services to the people and institutions in the state. The Office was housed in the Geography Department at UNC-CH. Many of the early users of the service were geographers - often educators in schools and colleges and many of their students. Over the next 25 years the SCO grew and expanded, the office moved to NCSU, and the NC State Climate Program developed as an inter-university entity. At the 25th Anniversary it is useful to remind everyone of the services offered by the Office, and to look at where we have been and where we can go in providing better and wider service. This is a brief report of the history and current plans. Comments to the author are very welcome.

For many years up until 1973 there was a federal program of state climatologists. They were primarily involved in work with the agricultural community. In that year the program was terminated, with the federal government encouraging the states to take over the abandoned functions. So, in 1976 there was a joint

agreement between the University of North Carolina system and the National Climatic Data Center to start the Office in NC. Peter Robinson was the first State Climatologist.

In those early days the budget was tight (nothing changes) and the main services provided were responding to requests for information. In 1976 a telephone represented fast communication, and a photocopier was high-tech. Requests came by mail or telephone. Most responses were either mailed copies of parts of the NCDC publications or numbers dictated over the phone. Agriculture and education provided the bulk of the requests. But this was also the time of oil crises and gas lines. So there were many requests for information related to energy, and the State Climate Office was involved in research into alternative sources.

The first expansion occurred in 1980, when the Office moved from UNC-CH to NCSU. At the same time the NC State Climate Program was organized as a joint effort between the two campuses. Although the State Climatologist, Jerry Davies, was housed in



the Department of Marine, Earth and Atmospheric Sciences, close connections were established with the College of Agriculture. This connection led to the development of a series of weather observing stations complementing in both parameters measured and geographical location, the stations of the National Weather Service. During this time, technology also changed. Data became electronic and an easily accessible data base was created. Faster response to more detailed requests became the order of the day.

From a start in the middle 1990s under the direction of the current State Climatologist, Sethu Raman, the agriculture-based observing system, now known as ECO-net, is being transformed into a denser network covering more aspects of the environment and more places in the state. Modern technology now allows the measurements to be available through the SCO home page in near-real time. Indeed, many more data are now available online. Check the home page at <http://www.nc-climate.ncsu.edu>. Despite this new technology, the Office still has phone lines, and many, many requests come by phone (919-515-3056).

The 25th Anniversary was celebrated on October 26th 2001, with a day-long gathering on the Centennial Campus of North Carolina State University. In the morning system President Molly Corbett Broad briefly reviewed the development of the Office and then officially inaugurated the ECO-Net as an hourly real-time climate data collection network with 25 stations scattered across the state. Others in attendance, including the Chancellor of NCSU and representatives of UNC-CH and several state and federal agencies, emphasized the many and various needs of the state and nation for the type of information provided by the State Climate Office. This part of the proceedings was concluded with a Keynote Address on climate, climate observations and climate change, by Tom Karl, Director of the National Climatic Data Center.

The rest of the day was spent exploring future directions. Presentations and panels with representatives of federal, state and local agencies and representatives of various universities - including several geographers - explored the information needs of the state and its people, the research and education needed to produce the information, and the mechanisms for actually providing information to

users. There are great needs for research, pure and applied, statewide and local, complex and simple. Plans are being developed to expand the State Climate Program to include any and all institutions of higher education, public or private, and anyone with an interest in climate or its impacts. If you fit, or think you might fit, let me know.

The State Climate Office and the State Climate Program are designed to assist everyone - especially geographers! - who has a need for climate information. Use the services, and join us in the Program.



Department of Geography

PROGRAMS AND RESEARCH FACILITIES

Undergraduate tracks include the B.A. in Geography and the B.S. in Applied Geography. The former is a broadly-based geography program, drawing courses from human and physical geography, as well as techniques. The latter has a strong emphasis on spatial analysis, and requires an internship in a state agency or private firm.

At the graduate level the Department specializes in human geography, physical geography and spatial information technologies, and supports a variety of philosophical and methodological approaches within each of these areas. Students are encouraged to develop their research in conjunction with faculty, and to disseminate their findings via professional meetings and journals. Faculty expertise is clustered around the following:

Economic Geography: development policies, practices, and impacts; urban and rural restructuring; and geographic thought (political economy, feminist theory, critical geopolitics).

Cultural Geography: community development; tourist landscapes; cultural ecology; and field methods.

Coastal Plain Geomorphology: coastal geomorphology (aeolian processes and dune formation); drainage basin hydrology; fluvial geomorphology; soil geomorphology; and environmental management (natural hazards research, land and water use planning).

Spatial Information Technologies: geographic information systems (watershed/ environmental modeling, topographic effects on digital data); remote sensing and image processing, computer cartography (global databases and map projections), and spatial quantitative methods.

Regional Specializations: Africa-East; Africa-South; Asia-South; Caribbean; Middle East; North Carolina; Western Europe.

Faculty are actively engaged in research in all four clusters, and have received multiple-year grants from, amongst others, the U.S. Department of Agriculture, the National Science Foundation, the New Jersey Sea Grant Program, N.A.S.A. and the U.S. Forest Service.

The department maintains both a fully equipped physical geography laboratory and a Unix-based Spatial Data Analysis Laboratory. The physical geography laboratory is designed for mechanical analyses of soil and sediment, but also includes state-of-the-art GPS, electronic surveying equipment, and instrumentation for monitoring hydrologic and aeolian processes and responses. The spatial laboratory consists of ten Sun workstations, a large format digitizer, and an Esize DesignJet plotter for teaching and research. Primary software includes Arc/Info, ArcView, and Imagine. A PC-based cartography laboratory was recently established. Students also have access to a wide variety of university facilities including the Institute for Coastal and Marine Resources, the Regional Development Institute, International Programs, and the Y.H. Kim Social Sciences Computer Laboratory. The Kim laboratory provides access to PC-based software such as Adobe Illustrator, ArcView, Atlas*GIS, IDRISI, SAS, SPSS, and Surfer.

FOR CATALOG AND FURTHER INFORMATION WRITE TO:

Undergraduate Catalog: Director of Admissions, Office of Undergraduate Admissions, East Carolina University, Greenville, North Carolina 27858-4353. Tel.: (919) 328-6640. World Wide Web: <http://www.ecu.edu/geog>

Graduate Catalog: Graduate School, East Carolina University, Greenville, North Carolina 27858-4353. Tel.: (919) 328-6012. Fax: (919) 328-6054.



APPALACHIAN STATE UNIVERSITY

Department of Geography & Planning

www.geo.appstate.edu

DEGREES OFFERED

- B.A. in Geography
- B.S. in Geography (teaching)
- B.S. in Geography (general concentration)
- B.S. in Geography (geographic information systems)
- B.S. in Community and Regional Planning
- M.A. in Geography with liberal arts option (thesis or applied)

RESEARCH FACILITIES

The Department occupies the third and fourth floors of a soon-to-be renovated science facility adjacent to the main library and contains four computer laboratories for work in computer cartography, GIS, and image processing. The laboratories have numerous microcomputers and SUN workstations, which are networked to each other and to the campus mainframe cluster. Appropriate peripherals include digitizers, scanners, printers, and plotters. The Department maintains a full suite of professional GIS, image processing, graphic design and statistical software applications in its laboratories. The Department is a USGS repository, and its map library presently possesses over 100,000 maps and 5,000 volumes of atlases, journals, and periodicals; and is also a repository for census material available on CD-ROM including TIGER files, DLGs, and other digital data. Other facilities include a large cartographic laboratory, research space, space for remote sensing, and telephone linkage to department-maintained weather stations for research in microclimatology.

GRADUATE PROGRAM

The Masters program in geography is designed to provide students with a relatively broad range of academic and professional options, preparing them for Ph.D. work in geography and planning, professional applications in GIS, or opportunities in teaching at all educational levels. Accordingly, concentrations are offered in liberal arts with thesis or in applied geography with internship in regional, urban, and environmental analysis and planning. In addition, the Department participates in a program leading to the Master of Arts degree in Social Science with preparation in geographic education.

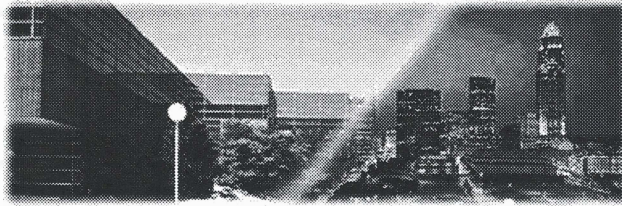
For further information, please contact:

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 Graduate Program Coordinator: Dr. Peter Soulé (soulept@appstate.edu)
 Program Inquiries: Kathy Brown (brownkv@appstate.edu)

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THE UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE

Master of Arts in Geography



The MA in Geography at UNC Charlotte emphasizes the application of skills, methods, and theory to problem solving in contemporary society. Students are offered a solid foundation in research methods, problem formulation, quantitative methods and computer and GIS skills. Many UNCC graduates have gone directly into jobs working as professional geographers using skills acquired in their MA program. Jobs include research and/or marketing specialists, location analysts, planners, transportation specialists and private consultants. About 15% of the more than 100 graduates have gone on to study in Ph.D. programs.

CHARACTERISTICS

- About 55-60 students and 23 faculty are in residence
- Class sizes are small; student and faculty are in close contact; community involved in class projects
- Funding is available on a competitive basis; about half of all full-time, current students have funding
- Excellent Spatial Analysis Laboratory with ARC/INFO GIS (workstation and PC) and ERDAS (workstation)
- The Department manages the Center for Transportation Studies which contains a research laboratory

PROGRAM CONCENTRATIONS

Community Planning Track

Students who choose the Community Planning track are awarded an M.A. in Geography and complete a formally structured multi-disciplinary core which includes course work in Geography, Architecture, Economics and Public Administration.

Urban-Regional Analysis and Planning

Students in the urban-regional analysis and planning concentration normally become planners in public sector planning agencies. Course work concentration is in one of the following areas:

Planning Theory	Public Facility Siting	Regional Development
Urban Theory	Environmental Planning	Site Feasibility Analysis
Urban Planning	Impact Analysis	

Location Analysis

The Location Analysis concentration prepares students for jobs in location research with retail companies, real estate developers, consulting firms, commercial banks, and economic development agencies or for continued academic training in economic geography and location analysis. Course work is offered in:

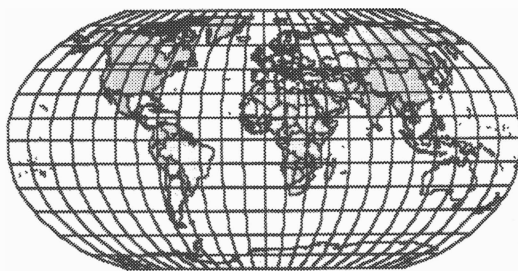
Retail Location	Trade Area Analysis	Facility Siting
Office and Industrial Location	Real Estate Development	Applied Population Analysis

Transportation Studies

Students in Transportation studies can pursue course work in transportation systems analysis, policy formulation, impact analysis, and planning. This concentration prepares students for jobs in the public sector as planners and in the private sector as analysts for transportation providers and private consulting firms.

THE INTERNSHIP As a program which emphasizes applied geography, the Internship is an especially important element and normally replaces the traditional thesis as the capstone project of a graduate program. Projects normally involve the students in the execution of a substantive research task for private or public sector clients where the student is the primary investigator in a specific "real world" research task.

FOR FURTHER INFORMATION CONTACT: Dr. Tyrel G. Moore, Graduate Coordinator
Department of Geography and Earth Sciences, UNCC, Charlotte, NC 28223 (704-687-4250)



GEOGRAPHY
AT
UNIVERSITY OF NORTH CAROLINA AT WILMINGTON

Geography at the University of North Carolina at Wilmington is housed in the Department of Earth Sciences. There are six full-time geography faculty. Research interests and specialties include: cultural-historical geography; material culture studies; environmental planning; and fluvial geomorphology. Equipment available for teaching and research includes modern PC-based cartographic and image-processing lab, and photographic and darkroom facilities. The university library contains a strong geography collection including all major journals, and is a repository for government documents and maps. About 40 majors are currently working towards a B.A. in geography.

Wilmington, North Carolina's premier port city, is located on the Cape Fear River and is only ten miles from the Atlantic shore. It is linked to the research Triangle area directly via Interstate 40. With a metropolitan area of over 130,000 residents, Wilmington is the economic and cultural hub of southeastern North Carolina. Climate is warm and humid during the summer, and exceptionally pleasant during the rest of the year, enhancing the variety of coastal recreational activities of the region.

For further information on our undergraduate program contact:

Dr. Frank Ainsley
Department of Earth Sciences
The University of North Carolina at Wilmington
Wilmington, NC 28403
TEL: (910) 962-3490
FAX: (910) 962-7077

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO



UNDERGRADUATE PROGRAM:

The geography major can choose a concentration in Urban Planning or Earth Science/ Environmental Studies. Currently, there are about 80 majors.

MASTERS IN APPLIED GEOGRAPHY:

The program requires 30 hours in geography, including a thesis or internship, plus two courses in statistics or computer science. The program has nearly 30 students and offers several graduate assistantships

FACILITIES:

The Geography Department houses a state-of-the-art research and teaching lab for GIS, computer cartography, digital image processing, and air photo interpretation. There are 20 networked pentium pro machines on an NT operating system, plus several printers, scanners and digitizing boards, as well as GPS equipment. Software used in the lab includes Arc/Info, ArcView, ERDAS, Surfer, Atlas GIS, MapInfo, ER Mapper, Adobe Illustrator, Adobe Photoshop and Corel Draw. There is also a climatology and SPSS computer lab, faculty/grad student research lab, geomorphology/geology lab, and a 100+ acre field camp to study geomorphology, meteorology, biogeography, and GPS mapping.

SPECIAL ACTIVITIES:

Students can become involved in the department, University, and community while becoming better acquainted with other students, faculty, employers and community leaders. The department hosts lectures bi-monthly at Geography Club meetings and sponsors several campus-wide events. Students can join the campus chapter of Gamma Theta Upsilon, the international geography honor society, and participate on UNCG's Geography Bowl Team in state competition. Many students take the summer field course to the West.

For Undergraduate Information:
Call: 336-334-3911
E-mail: KGDebbag@UNCG.EDU

For Graduate Information:
Call: 336-334-3895 or 3918
E-mail: Hidore@UNCG.EDU or
JCPatton@UNCG.EDU

Guidelines for Authors

The North Carolina Geographer is an annual, peer-reviewed journal published by the North Carolina Geographical Society. The journal serves as an outlet for research related to the geographical phenomena of local interest.

All manuscripts submitted to the North Carolina Geographer should be in acceptable form and ready for peer-review. Contributions should adhere to the following general guidelines.

- Send one original and two copies of manuscripts. Only original, unpublished material will be accepted
- All manuscripts should be on 8½" x 11" paper. Type on only one side of the page. Type should be 10 or 12 point font and double spaced. One inch margins should be used on all sides.
- References are to be listed on separate pages, double spaced, and in alphabetical order by authors last name.
- Figures and tables should be submitted on separate pages with each copy of the manuscript.
- High quality, black and white photographs may be included.

Send manuscripts to:

The North Carolina Geographer
Department of Geography
East Carolina University
Greenville, North Carolina 27858-4353
Telephone: (252) 328-6087 or (252) 328-6624
Fax: (252) 328-6054
E-mail: popkee@mail.ecu.edu or peasep@mail.ecu.edu

Minutes of the Annual Meeting of the North Carolina Geographical Society October 20, 2001

Many thanks to everyone in the Department at NCCU who housed us so hospitably. **Al Barnett** called this year's meeting to order with a compact agenda.

Treasurer's Report

Tom Whitmore presented the treasurer's report and noted that the organization is in good financial health with a bank balance \$1,499.83 (plus \$27.56 in the Credit Union's share/saving account) (as of 10/4/01). The balance at last year's meeting (9/11/00) was \$1,102.28. Major expenses over the period included the printing and mailing of the *North Carolina Geographer* (\$1,507) and the \$1.00 monthly fee for the Credit Union. Credits of \$1,091.29 included members' dues, institutional subscriptions, and a very small amount of interest.

Members discussed the costs of the NC World Geography Bowl, now covered by \$35 entrance fees for each team and a subsidy from UNC-G. It was unanimously approved to contribute \$100 from the treasury to UNC-G to help defray expenses. Members present at the meeting did not receive their renewal forms so no meeting fees were requested. It was decided that a \$10 fee be collected from all meeting attendees. Some concern was expressed that the printing subsidy (AKA ads) various departments have contributed to the journal in the past may dry up as a result of the state budget crunch. Until the actual date of publication, the extent (if any) of this possible loss is unknown. The treasury is sufficient to cover the expenses in any case.

North Carolina Geographer

One of our capable dual editors from ECU (**Jeff Popke**) noted that production of the new volume is in the process of final revisions. The issue will have 5 peer-reviewed articles as in the past: one from

the realm of GIS; one from physical geography, and 3 human geography pieces. While the quality of all the accepted articles is good, the number of submissions was small – members are encouraged to submit or encourage their students to do so.

It is planned to have it in the mail by the end of 2001 (it will be dated 2001). Last year 300 copies were run-off, but due to technical improvements (the entire journal is now on a CD ROM) we can if need be make a smaller initial production run and print more later as needed. 250 copies was the number arrived at for the initial printing. It was noted that at UNC-CH **John Florin** and **Peter Robinson** make extensive use of back issues (about 40) in their NC Geography class. Others are encouraged to follow their lead.

The perennial problem of publicity is to be addressed by an active presence at the SEDAAG meetings in Nov. to elicit subscribers and contributors. The editors will send copies of this year's journal to local newspapers and campus news bureaus in the home towns of the contributors in hopes to generate stories and interest. It was recommended that copies be sent to the Raleigh News and Observer's 'Newspapers in Education' editor, local community colleges, the NC Geographic Alliance newsletter editor and to high schools with AP Geography.

Jeff and **Patrick Pease** are happy to continue as editors and their continuance was warmly applauded.

Historian's Report

Our society historian, **Dot Mason**, has organized the documents she has been sent and can provide some historical blurbs to the web site in future.

NC World Geography Bowl (NCWGB)

Eight to nine teams were anticipated (see results above). As usual, question rounds are needed so sharpen those pencils. Everyone is welcome – especially teams that have never participated such as Elizabeth City or Fayetteville. Participation is a great morale builder and can even help with the Dean's opinions of a department.

Regarding dates for future NCWGBs, it was noted that earlier dates are preferred to miss fall breaks but they do present an organizational problem. Too late and there is too little time to assemble the NC team for the SEDAAG Geography Bowl. Overall, it was approved that the NCWGB should be held on either the last weekend in September or the first weekend in October. **Neal Lineback** and **Dennis Edgell** will look into the dates and make firm recommendations. **Neal, Dorothy,** and **Dennis** are warmly thanked for their untiring work for the Bowl. **Neal** noted that schools can rent the buzzer equipment that NCWGB now owns.

North Carolina Educator of the Year

As we decided last year, the NCGS steering committee was to select a "North Carolina Educator of the Year." The winner of that award this year is **Neal Lineback** of ASU. See photos number 8, 9, 11, and 12 at this link to see **Neal** receive his plaque, **Neal** and his plaque, and a detail of the beautiful plaque he received. **Ole Gade** agreed to contact the news bureau at ASU with the good news.

Election of Officers and other New Business

As is usual our outgoing vice President, **Dennis Edgell** (UNC-P), will assume the President's mantle. Congratulations **Dennis**. In an election by acclamation, **Derek Alderman** (ECU) was elected vice President. Many thanks to **Doug Carroll** for his service as president.

Derek will move off the steering committee to become VP. Thus, a new 3-yr term member was selected (in absentia), **Jeff Neff** of WCU. **Dennis**

was to contact **Jeff** with the good news. **Harlow Head** (Barton) has 1 year remaining on his appointment to the steering committee and **Harris Williams** (NCCU) has 2 years remaining on his.

ASU's department agreed to assume responsibility for next year's meeting. After examining university (football) and leaf color schedules, the exact date and location will be announced.

Al Barnett noted that NCCU has a new Chancellor who is receptive to Geography and he encouraged all members of the NCGS to try to include NCCU in activities because he believes that a greater profile will help the department in the Chancellor's eyes.

