

The North Carolina Geographer

Volume 14, 2006



FROM THE EDITORS

Dear Geographers,

In this volume of *The North Carolina Geographer*, we are excited to have research articles pertaining to streamflow and whitewater recreation in the western part of the state, Asian and Hispanic settlement patterns across the state, and Wilmington's rainwater chemistry. Due to Dot Mason's successful retirement, we will not have the presentation of a lesson plan from the 2005 North Carolina Geographical Society Educator of the Year. We do look forward to Jim Young's entry next year. As always, we encourage submissions of both research articles and Carolina Landscapes entries to the journal. Only through submission of manuscripts will our journal remain vital and sustainable. Remember, the goal of the journal is to highlight research on the geography of North Carolina, and topics of interest to geographers in North Carolina. Submit a manuscript yourself or encourage your colleagues and students to submit. We are currently accepting submission for the 2007 issue.

Thanks for your continued support of *The North Carolina Geographer*!

Sincerely,

Mike Benedetti (editor for physical geography)

Doug Gamble (editor for Carolina Landscapes)

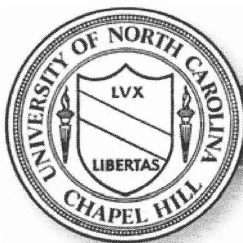
Joanne Halls (editor for applied geography)

Liz Hines (editor for human geography)

About the Cover

Doug Gamble (UNC Wilmington) took this picture of the sun setting over Roanoke Sound at Kill Devil Hills, NC June, 2007.

Authors alone are responsible for opinions voiced in this journal. Please direct inquiries concerning subscriptions and availability of past issues to the Editors. Back issues of the *North Carolina Geographer* are available for \$6 per copy.



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 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 17 faculty, including national and international leaders in areas of human geography, earth systems science and geographic information science. Geography offers the B.A., M.A., and Ph.D. degrees, with most graduate students pursuing the doctorate. The department enjoys excellent collaboration with a set of leading interdisciplinary programs on campus, including the Carolina Population Center, Carolina Environment Program, Shep Center for Health Services Research, Center for Urban and Regional Science, International Studies and Latin American Studies.

Undergraduate Program. UNC's Department of Geography offers a broadly based B.A. degree with concentration in three areas—the geography of human activity, earth systems science, and geographic information sciences. A well-equipped teaching lab directly supports undergraduate teaching and research in Geography, while a range of state-of-the-art facilities can be found at several venues on campus. Students are urged to participate in the University's superior undergraduate programs and resources, undergraduate research, and internships. The department has an undergraduate student exchange program with Kings College London and is developing a new joint degree program with the National University of Singapore.

Graduate Program. Our graduate program reflects our ongoing commitment to the highest quality research and our intention to continue to direct resources toward our primary research strengths: Earth Systems Science, Geographical Information Sciences, Globalization, Social Spaces, and Human-Nature Studies. These areas are integrated in individual and group research projects, while interdisciplinary cooperation is also highly valued. Reciprocal agreements with other universities in the Triangle allow graduate students to take courses at Duke University and North Carolina State. Funding is available through fellowship, research assistantships and teaching assistantships. Current graduate research is carried out both locally and globally on six continents with funding from a range of agencies including NSF, NASA, USDA, HUD, NIH and EPA as well as a set of private endowments. Recent graduates have regularly found positions in leading universities, government agencies and private enterprise.

For more information, contact Dr. Larry Band, Chair, Department of Geography, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3220. Telephone: (919) 962-8901. Email: lband@email.unc.edu

The North Carolina Geographer

Volume 14, 2006



Research Articles

- Streamflow Duration and Recreational Flows on Three Southeastern Streams1
Michael W. Mayfield, Appalachian State University
- Asian and Hispanic Settlement Patterns in the Counties of North Carolina, 200013
Evelyn D. Ravuri, Saginaw Valley State University
- The Effects of Local Weather Patterns on Nitrate and Sulfate Rainwater Concentrations in
Wilmington, North Carolina29
*Sarah Beth Jenkins, Douglas W. Gamble, Michael M. Benedetti, and Joan Willey, Univeristy of
North Carolina Wilmington*

Carolina Landscapes

Book Review

- North Carolina Weather and Climate. Peter J. Robinson, The University of North Carolina
Press, Chapel Hill, North Carolina, 2005. , 256 pp.39
Sol Wuensch, East Carolina University
- Request for Submissions & Guide for Authors.....46

About the Authors

Michael W. Mayfield is a Professor of Geography at Appalachian State University. His interests include physical geography, global change, and hydrology.

Evelyn Ravuri is an Assistant Professor of Geography at Saginaw Valley State University. Her interests included human georgaphy and ethnic migration.

Sarah Beth Jenkins received a B.A. in Geography from UNC Wilmington Spring 2007. The research presented in this volume was drawn from her senior honors thesis. Currently she is working in real estate law.

Douglas W. Gamble is an Associate Professor of Geography at UNC Wilmington. His teaching and research interests include applied climatology, hydrology, and coastal and island environments.

Michael Benedetti is an Associate Professor of Geography at UNC Wilmington. His teaching and research interests include fluvial geomorphology, Quaternary environments, and soils.

Joan Willey is a Professor of Chemistry at UNC Wilmington. Her teaching and research interests include the chemistry of rain and seawater, and air-sea exchange processes.

Sol Wuensch is graduate student at East Carolina University working towards his Masters degree in Geogra-phy. His thesis entails a comparison of surface and satellite measurements of extreme precipitation in the Carolinas.

Streamflow Duration and Recreational Flows on Three Southeastern Streams

Michael W. Mayfield
Appalachian State University

Whitewater boating has become an important part of the economy and has significantly changed the cultural landscape of numerous communities in the Southeast. In this paper I examine the flow duration statistics for three Southeastern streams to determine how often they typically flow at rates sufficient for kayaking and rafting. Those three streams are shown to have substantial differences in the frequency with which flows are adequately sustained for whitewater boating; the Nolichucky averages over 300 opportunity days per year, while the Watauga and Emory average fewer than 100 opportunity days per year. Reasons for those differences are examined and related to a combination of climatic and geomorphic factors. Decadal and inter-annual variability of flows for the three streams are examined and temporal trends discussed.

Introduction

Whitewater boating has become an important part of the economy and has significantly changed the cultural landscape of numerous communities in the southeastern United States (Mayfield and DeHart 1989; Pyle 2000). The Nantahala River of western North Carolina records over 200,000 whitewater user days per year, generating over \$14 million for the economy of Swain County (American Whitewater 2006a). American Whitewater negotiated recreational releases for the Cheoah River of Graham County that began in 2005. With at least 16 days of annual releases per year, the impact on the local economy is expected to start at \$3.0 million per year (American Whitewater 2006a). Many of the rivers that are heavily used for whitewater recreation in the Southeast are dammed and thus subject to flow regulation. Flow regulation serves to provide reliable streamflow levels for boating that are often scheduled months in advance of release dates. The Nantahala and Cheoah Rivers

are examples; recreational release schedules are published up to a year in advance for the Cheoah (American Whitewater 2006b). Regulated flow regimes therefore make recreational boating easy to schedule and also have important impacts on fluvial dynamics and the structure of rapids (Graf 1980; Mills 1990).

The whitewater section of the Cheoah River is entirely bypassed by a penstock that kept the riverbed dry for some seventy years until a river advocacy group negotiated with the dam operator for recreational releases as part of dam relicensing (American Whitewater 2006b). Due to the agreement, the river flows for just sixteen days per year but those days are known well in advance and boaters from across the eastern United States plan trips to the Cheoah for the release dates. Conversely, the Nantahala release schedule is not determined in advance, but it is quite reliable. The commonly paddled section of the Nantahala is below the hydroelectric power

plant, so whitewater recreation is possible whenever power is being generated, which occurs nearly every day of the year except during November, when dam maintenance occurs (American Whitewater 2007).

This paper focuses on three free flowing whitewater rivers in the Southeast, the Nolichucky (NC and TN), Obed-Emory (TN), and Watauga (NC and TN) (Figure 1). These streams are essentially free of impoundments; their flow regimes are based entirely on local climatological conditions rather than being determined by electrical demand schedules or transportation flow requirements. While many paddlers express a preference for free flowing streams (Abbey 1982; Woodward 2006), the variability of natural streamflow often makes it impossible to plan a kayaking or rafting excursion even a day in advance. In this paper I examine the flow duration statistics of three Southeastern whitewater streams in comparison to minimum flow requirements for boating.

The Study Streams

The Nolichucky River drains a watershed of 805 mi.² above the gage at Embreeville, TN (gage 03465500, USGS 2007a). The stream originates on the flanks of Mt. Mitchell, the highest peak east of the Mississippi. The river has Class III-IV rapids and is regularly used for commercial rafting during the late spring and summer months (Benner and Benner 2006). The Obed-Emory River drains a watershed of similar size (764 mi.² at USGS gage 0340500) on the Cumberland Plateau of Tennessee (USGS 2007b). The Emory watershed contains a wide variety of boatable river reaches, from Class I to Class V (Sehlinger and Lantz 1979). Flow statistics cited here refer to flows on the Class II-IV lower Obed section of the watershed. The Watauga is by far the smallest of the three watersheds, with a drainage basin encompassing only 92 mi.² (gage 03479000, USGS 2007c). Rapids within the gorge section of the Watauga are rated as Class IV-V (Benner and

Benner 2006). The Watauga Gorge is not regularly used for commercial rafting, due at least in part to the challenging nature of the rapids and presumably, the unreliable nature of its flow regime. Opportunistic kayakers are known to drive from as far away as Florida and Colorado to attempt its rapids when flows are appropriate.

The three watersheds are all within a three hour drive of Knoxville, Asheville, and Johnson City. Atlanta, Raleigh, and Charlotte are within a six hour drive of each of these rivers and most of the eastern seaboard is within a one-day drive of each. Kayakers typically decide where to travel for a week-end of paddling by checking current flow levels online. Those who go rafting with commercial outfitters more commonly choose a destination and a time well in advance as part of a planned vacation.

Flow Regimes

The interaction between channel materials and shear stress generated by peak flows is generally responsible for river channel configuration. River channel configurations that confine flow to a single thread are more likely to result in the ability of whitewater craft to descend a reach at low flows than if multiple threads are common. The rapids of these three streams result from a combination of bedrock ledges, boulder deposits, and large blocks delivered to the stream channel directly from adjacent cliffs. Personal observation of those rapids on the three streams for the last thirty years has shown them to be exceedingly stable even in the presence of large floods (RI > 25 years). Examination of air photos dating to 1950 and dendrochronological analysis of the mid-channel deposits of the Obed revealed that those features are only minimally affected by floods with recurrence intervals greater than 25 years (Mayfield 1989).

What is the minimum level of flow at which a specific reach of a river can be floated by kayakers or rafters? Unfortunately, any answer to that question is somewhat arbitrary and largely individual. The answer depends in part on the type craft being used to navigate the river. A skilled kayaker paddling a modern whitewater kayak can generally navigate a

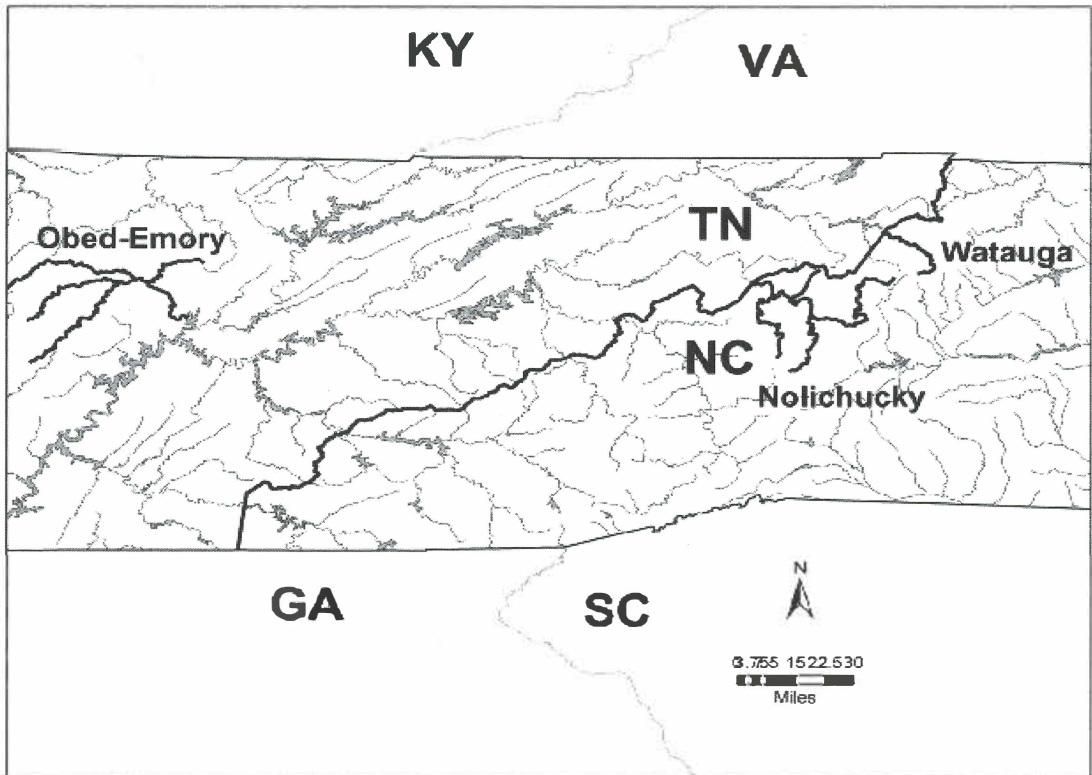


Figure 1. The Study Streams.

whitewater river at levels lower than can be achieved by a whitewater canoe or raft. Ultimately it becomes a matter of preference; while one guidebook recommends a minimum flow of 125 cfs for paddling the Watauga Gorge, very few boaters choose to do so (Benner and Benner 2006). A more practical minimum flow is 200 cfs, as expressed by numerous members of the local paddling community (Lambla 2007; Simpson 2007). Figure 2 shows the Watauga River at the minimal acceptable flow of 200 cfs. Fortunately, there are broadly accepted minimum flows that are developed by consensus within the whitewater community. Those recommended minimum flows are recorded in guide books as well as widely used web sites. The minimum flows used for this analysis are contained in Table 1.

While published minimum flows are generally accepted by large numbers of paddlers, maximum

flows are much more likely to engender debate and controversy. Minimum flow for boating is largely a function of river channel morphology relative to streamflow, while maximum acceptable flows are much more a function of boater skill, boat technology, and machismo. Skilled kayakers regularly paddle rivers at discharges that are several times greater than the recommended cutoff levels reported in guidebooks. Therefore I will limit discussion to minimum flows in this paper.

Mean daily streamflow values were downloaded from the USGS National Water Information System and processed to determine flow duration statistics (USGS 2007a, b, c). The period of study was 9/1/1940 through 12/31/2006, which is the common period of record for the three stream gages. The mean daily discharge is probably the best criterion available to determine flow duration statistics



Figure 2: The Watauga River at the minimum flow of 200 cfs. Photo by the author.

Table 1. Critical kayaking and rafting flows used in this study.

<i>River</i>	<i>Minimum flow (cfs)</i>	<i>Source</i>
Obed-Emory	1500	Sehlinger and Lantz 1979
Nolichucky	500	Benner and Benner 2006
Watauga	200	Consensus of local boating community

for the historical period but it is not without problems. For example, it is possible for the mean daily discharge to be somewhat below the accepted minimum threshold value, but for the river to flow at an adequate level for part of that day. If that acceptable flow occurs during daylight hours, it is possible for opportunistic boaters to “catch the bubble” and paddle the river. A good example is that on October 17, 2006 the Watauga River began the day flowing at a level well below 100 cfs (USGS 2007c). As rain fell throughout the day, the river level rose and exceeded the minimum flow level for several daylight hours (Figure 3). Even though the mean daily discharge of 170 cfs was below the 200 cfs threshold, it was indeed possible to paddle the Watauga in the late afternoon. A similar situation occurred on October 30 but with a much shorter window of opportunity. In both of those cases it would have been possible for a paddler living very close to the river to take advantage of the situation. However, it has been my experience that only a small number of kayakers living near Boone are able to take advantage of those opportunities because of the basin lag time, an average two hour delay in gage reports reaching Internet sites, and the driving time necessary to respond (Mayfield 2004). More importantly, most such situations occur in the summer with convective storms that occur in the mid- to late-afternoon. With a basin lag factor of approximately seven hours, the resulting high water reaches the threshold near midnight and subsides before the next morning. The Nolichucky and Obed rivers have much larger watersheds and considerably longer basin lag factors, so short duration events rarely result in boating opportunities.

Annual Streamflow Duration

An opportunity day is here defined as a day when the mean daily discharge of a river is above the minimum level recommended in published guidebooks. The only criterion considered is that of having adequate river discharge to float the designated section of the river. No attempt is made here to exclude days on the basis of excessively high water or

adverse weather. The average number of annual opportunity days for each of the three study streams is presented in Table 2.

The Nolichucky River has such well-sustained flows that it can be paddled nearly every day of an average year. As indicated in Table 2, the Nolichucky flows above the recommended minimum level of 500 cfs for an average of 304 days per year. Low flow duration characteristics of rivers are widely reported to be proportional to watershed size (Black 1996; Weaver 2001). The Nolichucky drains one of the larger, wetter watersheds of the southern Appalachians. It is not especially surprising that such a large watershed yields substantial low flows and a long boating season. However, the Obed-Emory River drains a watershed that is essentially equal in size to that of the Nolichucky but it yields an average of only 99 paddling days per year. That watershed has been shown to have an exceptionally flashy flow regime, considering its climate and terrain characteristics (Mayfield 1979). The extreme variability of flow was attributed to a general dearth of soil and bedrock storage within the watershed, compared to other streams in the region (Mayfield 1986). As a result of this flow regime, the Emory and its tributaries support very little commercial rafting and are paddled primarily by boaters in east Tennessee. Of the three streams, the Watauga has the shortest season with only 89 opportunity days per year.

Monthly Flow Duration

Monthly patterns of flow duration are significant in that they can indicate seasonal patterns of opportunities. Figures 4-6 reveal those monthly mean flow patterns. The Nolichucky River's mean monthly flow for each month of the year is above the recommended minimum level of 500 cfs, reinforcing the observation that its flows are well sustained. It is rare to find flows below the critical value of 500 cfs at any time of the year, so boaters often use the Nolichucky as a fall-back location to paddle if steeper, flashier streams lack adequate flow. Watauga River and Emory River flows again fall far short of those of the Nolichucky by

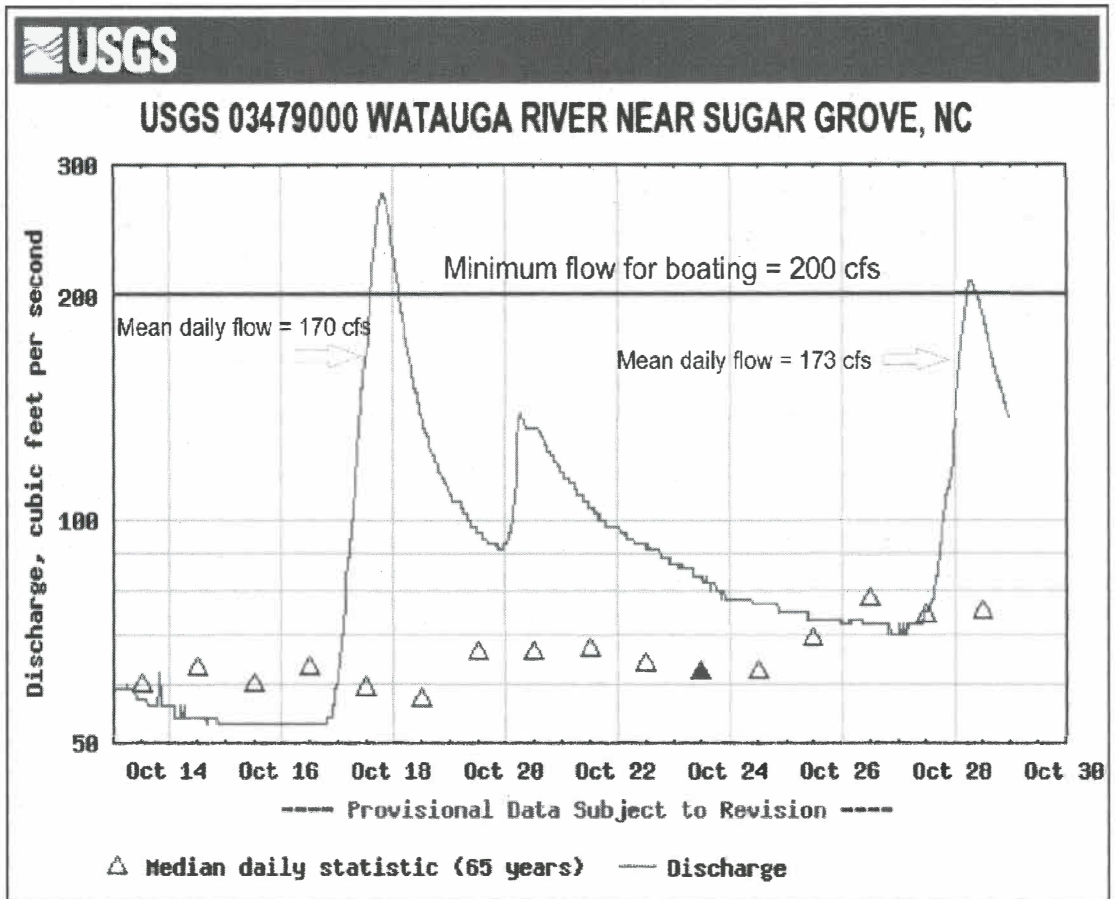


Figure 3: Discharge of the Watauga River, October 14-30 2006. Source: USGS 2007c.

Table 2. Average Number of Opportunity days per year on the three study rivers.

Source: Calculated from USGS (2007a, b, c).

<u>River</u>	<u>Number of Days</u>	<u>Percent of Days</u>
Obed-Emory	99	27.07
Nolichucky	304	83.29
Watauga	89	24.46

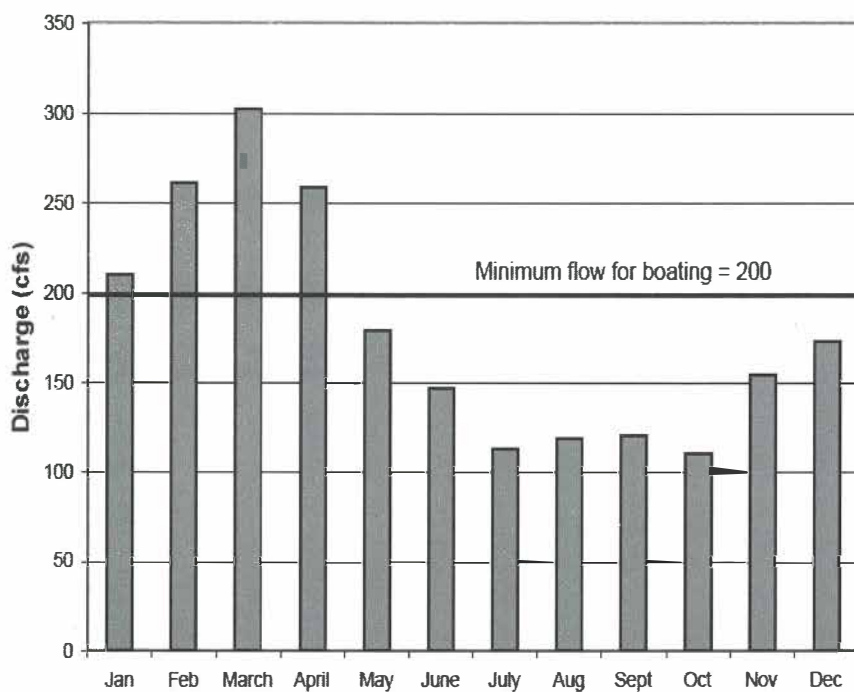


Figure 4: Mean monthly discharge of the Watauga River. Source: USGS 2007c.

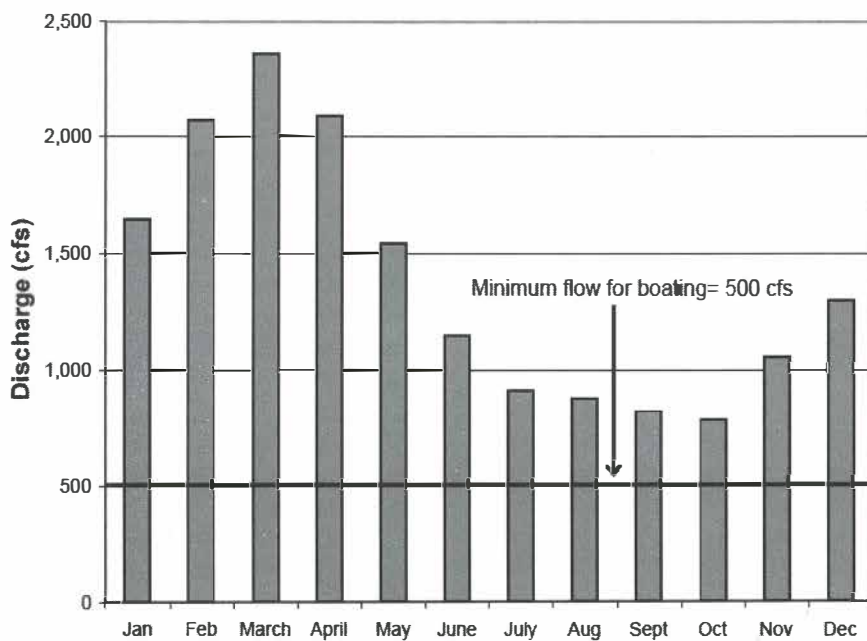


Figure 5: Mean monthly discharge of the Nolichucky River. Source: USGS 2007b.

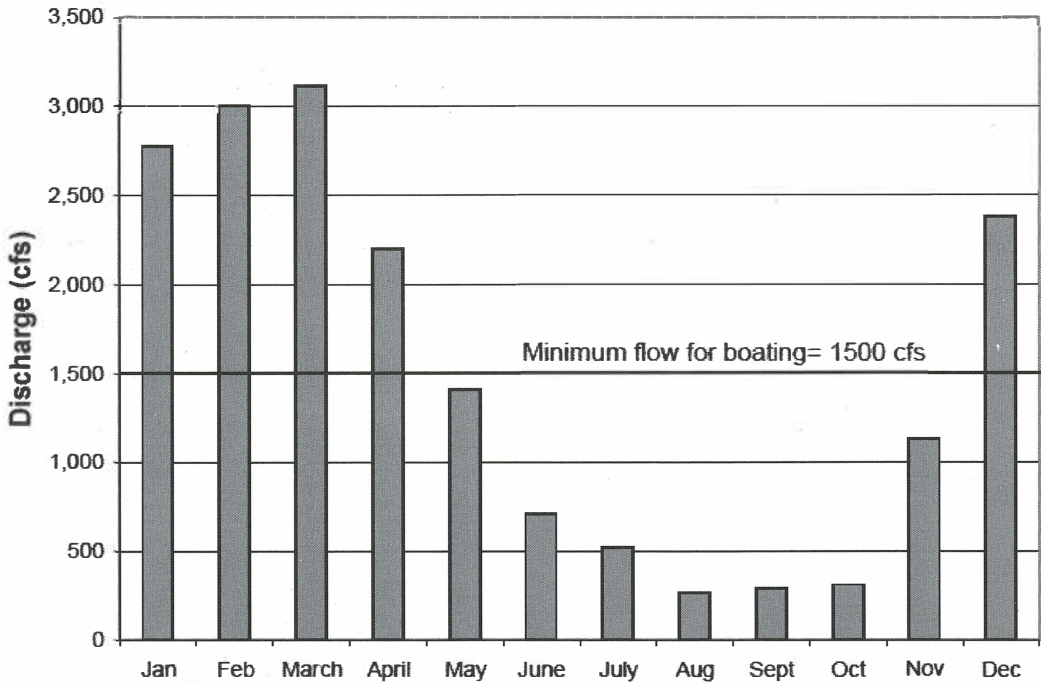


Figure 6: Mean monthly discharge of the Emory River. Source: USGS 2007a.

this measure. Mean monthly flows on the Emory are above the recommended minimum during only five months of the year; the Watauga River's mean monthly flows only exceed the minimum paddling level during four months of the year. All of those months are during the cold period of winter and early spring.

Opportunity days arise for the Watauga River throughout the year, even during the summer months when median monthly discharge values are at least 25% below the threshold for paddling. In this small watershed, a convective storm can yield enough runoff for the river to rise above the 200 cfs threshold. Conversely, the Emory River tends to flow at levels far below its threshold for the entire period of June through early November, with little chance of rising to its threshold value of 1500 cfs.

Inter-Annual Variability of Flows

Year-to-year variations in annual and seasonal precipitation in the Southern Appalachians and the Southeast in general have been attributed to a wide variety of atmospheric phenomena, including ENSO and the North Atlantic Oscillation (Henderson and Robinson 1994; Henderson and Vega 1996; NC SCO 2006; Zorn and Waylen 1997). Those variations can have substantial impacts on the number of opportunity days for a river such as the Watauga, as the river flows at levels very close to the threshold for paddling for much of the year. Figure 7 reveals that all three study streams have shown significant variations in the number of annual opportunity days over the last decade, but those variations have been greatest for the Watauga.

Annual precipitation and runoff has varied dramatically in the Watauga watershed during the last decade. Streamflow statistics for that period reveal that the mean annual flow varied from a low of 82 cfs in 1988 to a high of 273 in 1992. Other drought years such as the extended dry period from 1999

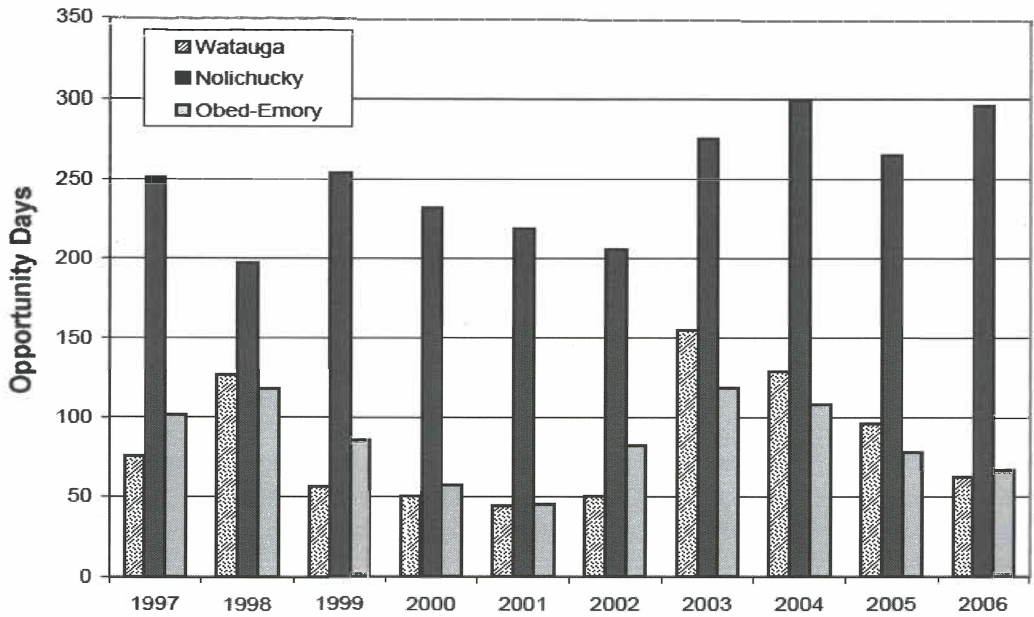


Figure 7: Annual kayak and raft paddling opportunity days. Source: Calculated from USGS 2007a,b,c.

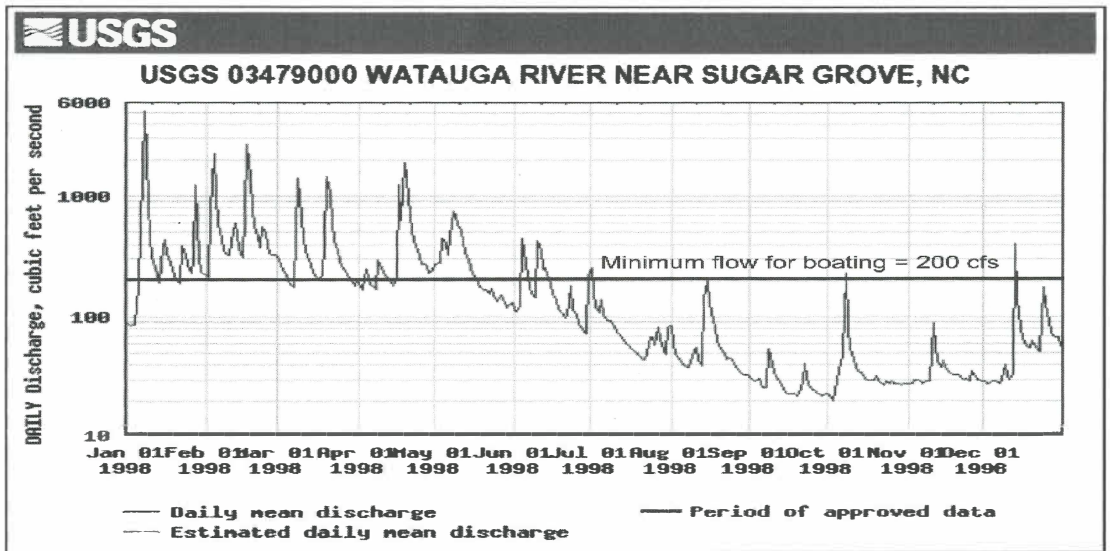


Figure 8: Mean Daily Discharge of the Watauga River, January 1-December 31, 1998. Source: USGS 2007c.

through 2002 were clearly associated with strong La Niña events, which have been found to be associated with prolonged drought in the Southeast in general and North Carolina in particular (NC SCO 2006; Robinson 2005). Significant flow variability is to be expected for a small mountain watershed. However, the fact that the median flow values for the Watauga are so close to the threshold for recreation use means that modest variations in flow can result in significant changes in the number of opportunity days.

The last decade has seen a substantial variation compared to the long-term (1940-2006) average of 24.46% of all days having more than the minimum flow. The period from 1999-2002 was clearly a tough time for kayakers in the North Carolina High Country and 2006 was almost as bad, although the onset of a moderate El Niño event coincided with a large number of opportunity days in late November and December.

Flow variability can be substantial even within a single calendar year. The strong El Niño event of the late 1990s ended abruptly with rapidly cooling tropical Pacific sea surface temperatures in June of that year (NOAA 2006). Substantial flow variability occurred during the 1998 calendar year, as there were 126 opportunity days on the Watauga prior to from January 1, 1998 until May 31, 1998 and only four opportunity days during the second half of the year (Figure 8). Future research will focus on an analysis of the relationships between the number of opportunity days for paddling on these streams and various climate indices, including NAO and ENSO.

Conclusions

Flow duration and reliability of flows are important variables when many paddlers decide where to go rafting or kayaking. The number of opportunity days to paddle a river each year is clearly an important variable in motivating boaters to select specific locations to paddle. Private investors recently built an artificial whitewater recreation center outside of Charlotte, with over \$37 million in government guaranteed funds (Willoughby 2006; USNWC 2007). One of the announced purposes was to provide reliable flows on demand. As a result of those

reliable flows, the facility was named the Olympic training center for whitewater canoeing and kayaking. Reliability of flow is of great importance for many whitewater paddlers, as noted for the Cheoah River.

Continued growth of the whitewater recreational industry is largely dependent upon precipitation patterns and resultant runoff rates that vary dramatically over even short periods of time in unregulated watersheds. On smaller rivers such as the Watauga and flashy rivers such as the Obed-Emory, those flows have been shown to be highly erratic. Numerical models have suggested that runoff in the Southeast is likely to decline in face of a warming climate during the 21st century (USGCRP 2006). The dry decade of the 1990s may prove to be a modest analog for leaner times to come for whitewater boaters if those model projections hold true.

References

- Abbey, E. 1982.** *Down the River*. New York: Dutton Publishers.
- American Whitewater.** 2007. Nantahala, NC. Online at <http://www.americanwhitewater.org/rivers/id/1101/>
- American Whitewater.** 2006a. The economic impacts of river recreation. Online at http://www.americanwhitewater.org/content/Wiki/stewardship:recreation_economics
- American Whitewater.** 2006b. Cheoah River release. Online at: <http://www.americanwhitewater.org/content/Calendar/view-date/event/1868/&event=1868>
- Benner, B. and D. Benner.** 2006. *Carolina Whitewater*, 9th ed. Birmingham: Menasha Ridge Press.
- Black, P. E.** 1996. *Watershed Hydrology*, 2nd Ed. Ann Arbor: Ann Arbor Press.

- Graf, W.** 1980. The effect of dam closure on downstream rapids. *Water Resources Research* 16: 129-136.
- Henderson, K.G. and P.J. Robinson.** 1994. Relationships between the Pacific/ North American teleconnection patterns and precipitation events in the south-eastern USA. *International Journal of Climatology* 14: 307-323.
- Henderson, K.G. and A.J. Vega.** 1996. Regional precipitation variability in the Southern United States. *Physical Geography* 17: 93-112.
- Lambla, Cooper.** January 14, 2007. Personal interview with the author.
- Mayfield, M.W.** 1979. Runoff in the ObedEmory Basin of Tennessee. *The Southeastern Geographer* 19: 54-65.
- Mayfield, M.W.** 1986. Hydrologic response of watersheds of the Cumberland Plateau, Tennessee. *The Southeastern Geographer* 25: 36-54.
- Mayfield, M.W.** 1989. Magnitude-frequency relationships of alluvial landforms of the Cumberland Plateau. *Southeastern Geographer* 29: 106-117.
- Mayfield, M.W. and J. DeHart.** 1989. Whitewater rafting in the Southeastern United States: current status and constraints on future growth. *Sport Place International* 3: 1419.
- Mayfield, M.W.** 2004. Hydrology of rainfed streams. *Lunch Video Magazine* print edition 12: 13-15.
- Mills, H.H.** 1990. Geologic and topographic controls on the rapids of the New River Gorge, West Virginia. *Southeastern Geology* 31: 45-62.
- National Oceanic and Atmospheric Administration (NOAA) CIRES Climate Diagnostics Center.** 2006. Multivariate ENSO index. Online at: <http://www.cdc.noaa.gov/people/klaus.wolter/MEI>
- North Carolina State Climate Office (NC SCO).** 2006. Aspects of NC climate: El Niño and La Niña. Online at <http://www.nc-climate.ncsu.edu/climate/enso.html>
- Pyle, L. A.** 2000. The whitewater industry in West Virginia, southwestern Pennsylvania and western Maryland. Patrick, Kevin J. and Scarpaci, Joseph L. Jr., eds., *A Geographic View of Pittsburgh and the Alleghenies: From Precambrian to Post-Industrial*. Washington DC: Association of American Geographers.
- Robinson, P.J.** 2005. *North Carolina Weather and Climate*. Chapel Hill: UNC Press.
- Sehlinger, B. and B. Lantz.** 1979. *A Canoeing and Kayaking Guide to the Streams of Tennessee*. Ann Arbor: Thomas Press.
- Simpson, David.** March 3, 2007. Personal interview with the author.
- United States Global Change Research Program (USGCRP).** 2006. The global water cycle. online at <http://www.usgcrp.gov/usgcrp/ProgramElements/water.htm>
- United States Geological Survey (USGS).** 2007a. USGS 03465500 Nolichucky River at Embreeville, TN. Online at: http://waterdata.usgs.gov/tn/nwis/nwisman/?site_no=03465500&agency_cd=USGS
- United States Geological Survey (USGS).** 2007b. USGS 03540500 Emory River at Oakdale. Online at: http://waterdata.usgs.gov/tn/nwis/inventory/?site_no=03540500&

United States Geological Survey (USGS). 2007c.

USGS 03479000 Watauga River at Sugar Grove. Online at: http://waterdata.usgs.gov/n c / n w i s / u v / ?site_no=03479000&agency_cd=USGS

United States National Whitewater Center (USNWC). 2007. Sports: Whitewater

kayaking. Online at: http://www.usnwc.org/sports_kayak.asp

Weaver, J.C., and Pope, B.F. 2001. Low-flow characteristics and discharge profiles for selected streams in the Cape Fear River Basin, North Carolina, through 1998. *U.S. Geological Survey Water-Resources Investigations Report* 01– 4094, 140 p.

Willoughby, Scott. 2006. New whitewater park concept takes hold with opening of N.C. facility. *Denver Post*, November 8, 2006. Online at: http://www.usoc.org/11789_49904.htm

Woodward, Doug. 2006. *Wherever Waters Flow: A Lifelong Love Affair with Wild Rivers*. Franklin, NC: Headwaters Publishing.

Zorn, Matthew and Peter R. Waylen. 1997. Seasonal response of mean monthly streamflow to El Niño/Southern Oscillation in north central Florida. *Professional Geographer* 49: 51-62.

Asian and Hispanic Settlement Patterns in the Counties of North Carolina, 2000

Evelyn D. Ravuri

Saginaw Valley State University

The Southeastern United States has received numerous Asian and Hispanic migrants since the 1980s. This paper examines the distribution of six Asian and Hispanic ethnic groups in North Carolina counties in 2000. Aggregate data at the national level pertaining to the educational attainment of each of the ethnic groups is used to provide insight about why certain ethnic groups are attracted to certain North Carolina counties. Asian groups were over-concentrated in the Raleigh-Durham-Chapel Hill and Charlotte metropolitan areas in comparison to their Hispanic counterparts. In these metropolitan areas are found the largest of North Carolina's universities, which attract many Asian students and provide the largest numbers of professional employment opportunities. Given that Asians have much higher educational levels than their Hispanic counterparts, it is not surprising that they are over-concentrated in the Raleigh and Charlotte Areas. The distribution of Mexicans and Central Americans was more dispersed throughout North Carolina because of the employment opportunities provided by the agricultural and meat-processing industries available to these groups. Puerto Ricans have long used the military as a vehicle to upward mobility and explains the over-concentration of this group in counties with a military base.

Introduction

A major change in immigration flows to the United States was underway by the 1960s as Latin American and Asian countries surpassed European countries as the major contributors of immigrants (Massey, 2001). Asian and Hispanic immigrants, as well as native-born Asians and Hispanics, are currently concentrated in six states (California, Florida, Texas, New York, New Jersey, and Illinois), but this pattern is changing. Since the 1980s, tens of thousands of Mexicans, Central Americans, and Vietnamese have settled in the Southeast to take advantage of low-skilled, low-wage occupations in carpet manufacturing (Hernandez-Leon and Zuniga, 2000), the poultry industry (Broadway, 1995; Horowitz and Miller, 1999) and agriculture (Fink, 2003). Asian Indians, Chinese, and other Asian groups have also moved to the Southeast for employment and educa-

tional opportunities in the rapidly growing cities of the Southeast such as Charlotte and Atlanta (Godziak, 2005). Today the South has become a multi-cultural region and this trend is likely to continue over the next century (Hartshorne, 1997; Shelley and Webster, 1998; Schimdt, 2003; Frazier, Margal, and Tettey-Fio, 2003).

Bump, Lowell, and Petterson (2005) categorized North Carolina as a new immigrant settlement region because during the 1990s North Carolina led the country with the highest percentage increase in Hispanic immigrants and was second only to Georgia in its percentage growth of Asian immigrants. Bailey (2005) noted that the major areas of settlement for recent immigrants to North Carolina during the 1990s were in the Triad (Winston-Salem, and Greensboro-High Point); the Research Triangle (Raleigh-Durham-Chapel Hill); and the cities of Char-

lotte and Asheville. Even though North Carolina has become a major immigrant growth pole, not all of the growth of the Hispanic and Asian population can be attributed to immigration. Internal migration of U.S.-born Hispanics and Asians from other regions of the U.S. has become an important generator of growth for these two populations in Southern states (Pandit, 1997). In addition, immigrants/migrants tend to be in the prime-child bearing years and tend to have higher birth rates than their non-immigrant white and black counterparts, which contribute to the rapid growth of both Hispanics and Asians (Durand, Telles, and Flashman, 2006; and U.S. Bureau of the Census, 2004a).

The purpose of this paper is to compare and contrast the distribution of six ethnic/racial subgroups of Hispanics and Asians in the 100 counties of North Carolina in 2000. The distribution of the non-immigrant white and black populations is used as a reference group in the comparison. The human capital model is used to explain differences in the distribution between the Asian and Hispanic groups. Human capital is defined as the assortment of skills and educational attainment that an individual brings to the labor market.

The paper is divided into five parts. First, the data sources and the reasoning behind the selection of the ethnic/racial groups are explained. Second, an overview of the physical and socioeconomic regions of North Carolina is discussed. Theoretical concerns relating to migration are addressed in the third section. In the fourth section, the distribution of the ethnic/racial groups is examined and discussed in reference to the human capital model. Finally, the conclusion suggests avenues for future research.

Data Sources and the Selection of the Six Groups

The 1990 and 2000 Censuses of Population Summary Tape Files 3 for North Carolina were used to gather the data for the number of individuals in each ethnic/racial group and for preparation of the maps. Data pertaining to the human capital or educational levels of the groups came from the Special Reports for Asians and

Hispanics (U.S. Bureau of the Census 2004a and 2004b).

Three Hispanic (Mexican, Central American, and Puerto Rican) and three Asian (Vietnamese, Asian Indian, and Chinese) groups were chosen for this descriptive analysis of their distribution in North Carolina. Each of the groups included in the analysis had at least 1,000 individuals in North Carolina in 1990 and experienced a 100.0 percent or greater population growth rate between 1990 and 2000. Other immigrant groups with a small 1990 base population, a small numerical increase during the 1990s, and thus a large percentage gain were not included in the analysis.

As a departure point for this study, the growth of the six ethnic/racial groups in North Carolina is considered (Figure 1). An examination of the change by individual counties would be cumbersome, although the growth and ethnic composition of individual counties cannot be ignored. However, the consideration of the state as a whole provides a synoptic view of these phenomena.

The Mexican population had the highest growth rate (759.9 percent) during the decade. North Carolina gained more than 200,000 Mexicans during the 1990s through the combined processes of immigration, internal migration, and natural increase. The 1990 census did not disaggregate Central Americans, so the "Other Hispanics" category, which was used for both the 1990 and 2000 Censuses, showed a growth rate of 265.2 percent. However, the Central American growth rate was probably higher than this combined figure given the recent influx of Central Americans. The Puerto Rican population grew most slowly (relative to the other Hispanic groups), but still increased by 154.8 percent.

The number of Asians in North Carolina is about one third that of Hispanics (111,817 versus 378,963, respectively, or 29.5 percent), although the Vietnamese population grew by 199.3 percent, the Indian population by 166.0 percent and Chinese by 103.4 percent. As a comparison, the non-Hispanic white and black populations grew by 13.6 and 15.9 percent, respectively.

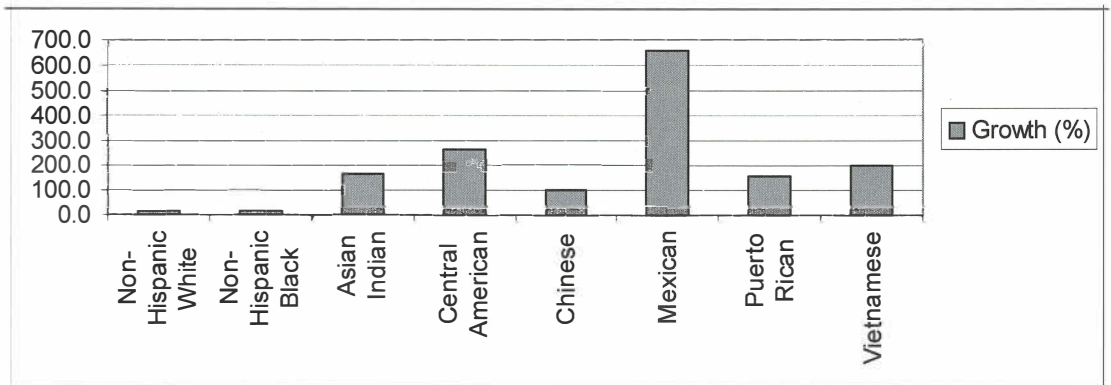


Figure 1. Percent Growth of Select Population in North Carolina, 1990-2000

Overview of North Carolina's Regions

Ole Gade (1996) grouped North Carolina's 100 counties into four categories based on the physical location and their social and economic characteristics. These were the Piedmont, Mountains, Coastal Plain, and Tidewater Regions (Figure 2). The Piedmont has 34 counties and five metropolitan regions (Charlotte, Raleigh-Durham-Chapel Hill, Greensboro-High Point, Winston-Salem, and Hickory-Lenoir-Morganton). The region is noted for its concentration of manufacturing and high-technology industries and has the highest socio-economic characteristics, as measured by educational levels of the population and per capita incomes, of North Carolina. Its rapid growth began in the 1960s as individuals from the Northeast and Midwest came to the South to escape the deindustrialization process that was underway in the manufacturing belt, commonly referred to as the rust belt phenomenon (Greenwood, 1988). The Raleigh-Durham-Chapel Hill area contains the Research Triangle, several renowned universities, and a high percentage of people employed in various professions. Greensboro-High Point and Winston-Salem also have several universities and a high percentage of that labor force is also engaged in professions. The occupational structure of Hickory-Lenoir-Morganton is manufacturing-based, while Charlotte has a more diversified economic structure (U.S. Department of Labor, 2006).

The Coastal Plain (23 counties), also known as the Eastern Agricultural Zone, contained only one

small metropolitan area in 1990 (Wilmington), but had three small cities, which by 2000 had attained status as metropolitan areas (Fayetteville, Goldsboro, and Wilmington). Socio-economic status in this region ranks second to that of the Piedmont. Non-metropolitan counties in this region are noted for agriculture and meat-processing facilities.

The western Mountain Region (25 counties) is relatively isolated and has some of North Carolina's poorest counties, Buncombe, where Asheville is located, being an exception. However, it is noted for its natural beauty and as a tourist/recreational zone as well as a retirement haven. Only one small metropolitan region, Asheville, is located within the region. This zone has long maintained an insular mountain culture comprised overwhelmingly of white ethnic groups. The Tidewater Zone (18 counties), although possessing the great tourist appeal of the Atlantic beaches on the famous barrier islands, contains several counties that are among the poorest in North Carolina. Access is also a problem for the Tidewater Region, which is not well connected by highway, rail or air, with other regions of North Carolina.

Theoretical Concerns

Macroeconomic theories of migration assume that migration streams will flow from low-wage regions to high-wage regions (Harris and Todaro, 1970; Ritchey, 1976). Since the 1960s, the United States, a

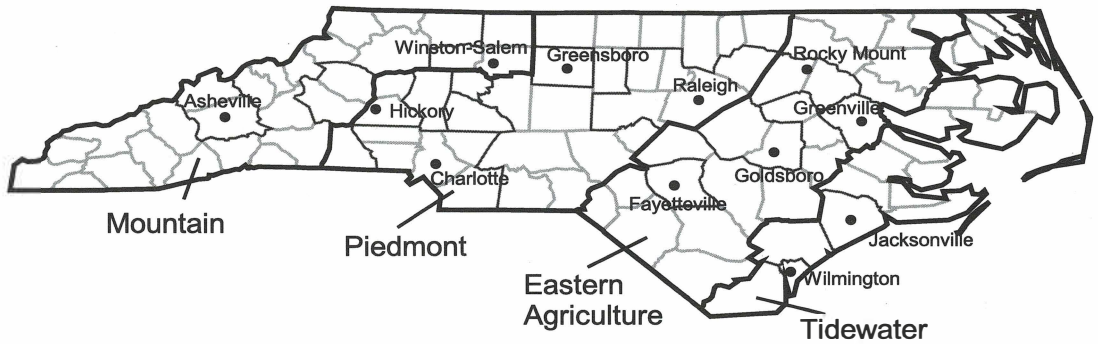


Figure 2. North Carolina's Regions and metropolitan areas.

high wage region, has drawn a greater percentage of its immigrants from low-wage regions such as Latin America and Asia (Massey, 2001). The idea that the basic motive for migration revolves around economic incentives originated with Ravenstein (1885) and his *laws of migration*, a proposed theory about human migration. Lee (1966) further developed migration theory by focusing on push and pull factors related to migration. Push factors expel individuals from one region while pull factors attract them to another region. From an economic perspective, poverty and unemployment at the origin may push a migrant from the source while higher wages and job opportunities may pull an individual to a destination.

Although macroeconomic theories are important in modeling migration flows, individual motives, or microeconomics, should also be considered when examining the rationale for migration. Sjaastad (1962) stated that the act of migration entails a calculus of costs and benefits. The potential migrant must weigh not only the cost of making a move but also the probability of finding employment, as well as the potential wages to be earned over a specific period of time.

Economists have introduced the concept of human capital (Becker, 1965; Schultz, 1970), which is an array of skills, on-the-job training, and educational attainment that makes an individual competitive in the labor market. Individuals who invest in education and receive on-the-job training early in their careers are more likely to achieve greater mon-

etary gains over their work lives. Sjaastad (1962) provides an important conceptual link between migration and human capital and states that migration is not a random behavior and thus does not draw from a cross-section of the population. Potential migrants are more likely to be drawn from the young adult years, because the amount of time to accrue benefits from the migration decision will be longer.

Borjas (1989) further explores the selective nature of migration by focusing on economic motives for immigration and found that immigrants can be either negatively or positively selected. Negatively selected immigrants earn low wages in the source country and also earn low wages in the destination country. Positively selected immigrants earn high wages in the source country and usually above average wages in the destination country. Although, Asian and Latin American immigrant flows are composed of both types of immigrants, the majority of Latin American immigrants are negatively selected, whereas a high percentage of Asian immigrants are positively selected.

This selectivity of migration explains why foreign-born as well as native-born Asians residing in the United States earn higher wages than their Latin American counterparts. The key to understanding these differentials in human capital relate to the idea of distance decay. According to Ravenstein's (1885) theory of migration, the more distant two places are from each other, the less the intensity the migration flow between those two places. Latin American

countries are closer to the United States than Asian countries and thus the costs associated with migration are less than the costs of migration from Asia. This reality provides the foundation for the disparities between human capital skills acquired by Asians versus Latin Americans. For the average Latin American, the journey to the U.S. is shorter than for the average Asian. Therefore, the vast disparity in standards of living between Latin American countries and the U.S., coupled with close proximity, allow individuals with limited economic resources and human capital skills to relocate with relative ease to the U.S. Although, standards of living in most Asian countries are also low, the costs associated with such a long-distance move preclude the exodus of many poorer individuals.

Distribution Patterns within North Carolina

Non-Hispanic white and Non-Hispanic black compared to Hispanic and Asian Groups

The large difference in raw numbers of each of the ethnic/racial groups dictated that percentages be used instead of actual numbers so that more accurate comparisons could be made between the distributional patterns within North Carolina for each of the ethnic/racial groups. Figures 3a-3h display the percentage of the total ethnic/racial group under consideration that is located within each of the counties of North Carolina.

A cursory view of the maps (Figures 3a-3h) shows that non-Hispanic whites and blacks are more dispersed throughout North Carolina than Hispanics (except Mexicans) and Asians. Only Wake County, where Raleigh is located, contained more than 7.8 percent of North Carolina's non-Hispanic white population, while Mecklenburg County, where Charlotte is located, had only 11.2 and 10.0 percent of North Carolina's non-Hispanic black and Mexican populations, respectively. Non-Hispanic whites and blacks have had the longest settlement history in North Carolina, and so it is not surprising that they have a more dispersed settlement pattern.¹ The sheer magnitude of the growth of the Mexican immigrant

population in comparison to that of the other immigrant groups may explain why they have become so dispersed throughout the state. North Carolina has long a long history of employing migratory Mexican agricultural labor (Johnson, Jr., Johnson-Webb and Farrell, Jr., 1999), many of whom now remain in North Carolina year round. At the other end of the spectrum, 32.6 percent of North Carolina's Vietnamese population lived in Mecklenburg County, 26.5 percent of the Chinese population lived in Wake County, and 24.9 percent of Puerto Ricans were found in Cumberland County, location of Fort Bragg.

A second difference between the reference populations and Hispanics and Asians is that non-Hispanic whites and blacks were less likely to reside in metropolitan areas than their Hispanic and Asian counterparts (Table 1). Unlike other regions of the U.S., the South has had a long history of non-Hispanic blacks residing in rural areas and probably explains why non-Hispanic blacks are not overrepresented in metropolitan areas.

Given the relatively recent migration of most of the Hispanic and Asian groups into North Carolina, it is not surprising that they are attracted to metropolitan areas. Difficulty with a new culture and language, and a host of other economic and social factors generally tend to concentrate immigrants in enclaves that provide a base from which they can become acclimated to their new surroundings (Allen and Turner, 2006). The largest metropolitan regions in the state (Charlotte and Raleigh) also provide the greatest number of non-agricultural employment opportunities, housing availability, and social contacts and thus attract more immigrants of all kinds.

Comparison of Hispanic and Asian Groups:

As stated previously, human capital is a set of characteristics that allows an individual to be competitive in the labor market. The most important measurement of human capital is the quantity and quality of education. It is well documented that most Asian ethnic groups have educational levels that exceed those of most Hispanic groups (Duncan, Hotz, and Trejo 2006; Sakamoto and Xie, 2006), and thus have higher human capital (Table 2). It is assumed that individuals from each immigrant group would

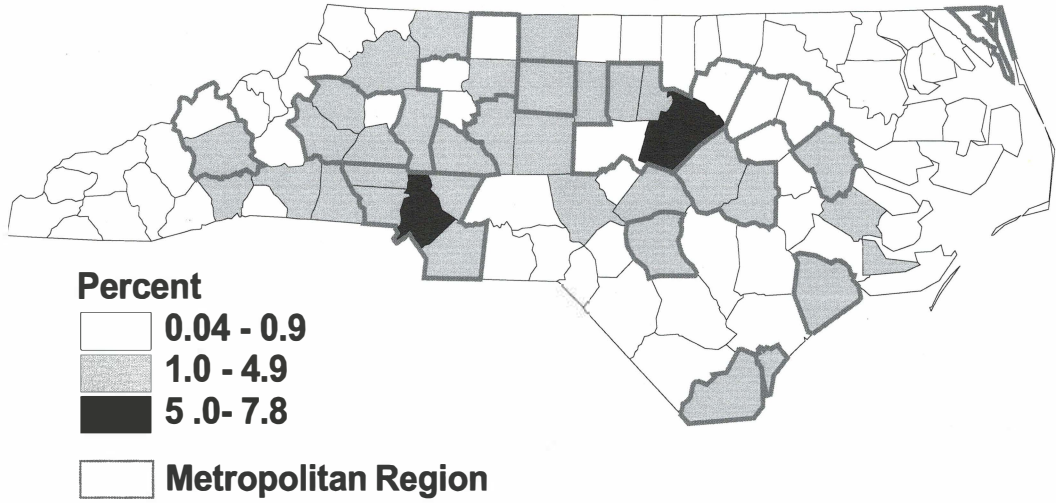


Figure 3a. Non-hispanic whites in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

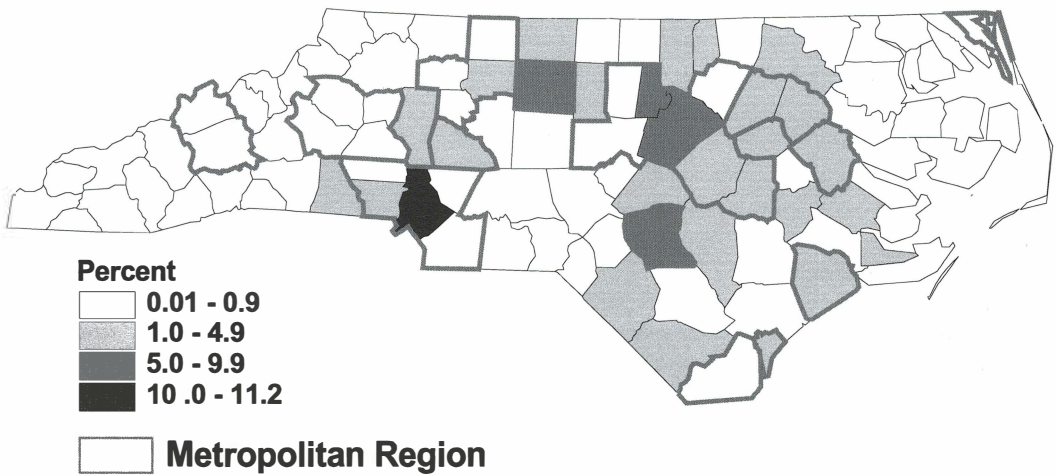


Figure 3b. Non-hispanic blacks in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

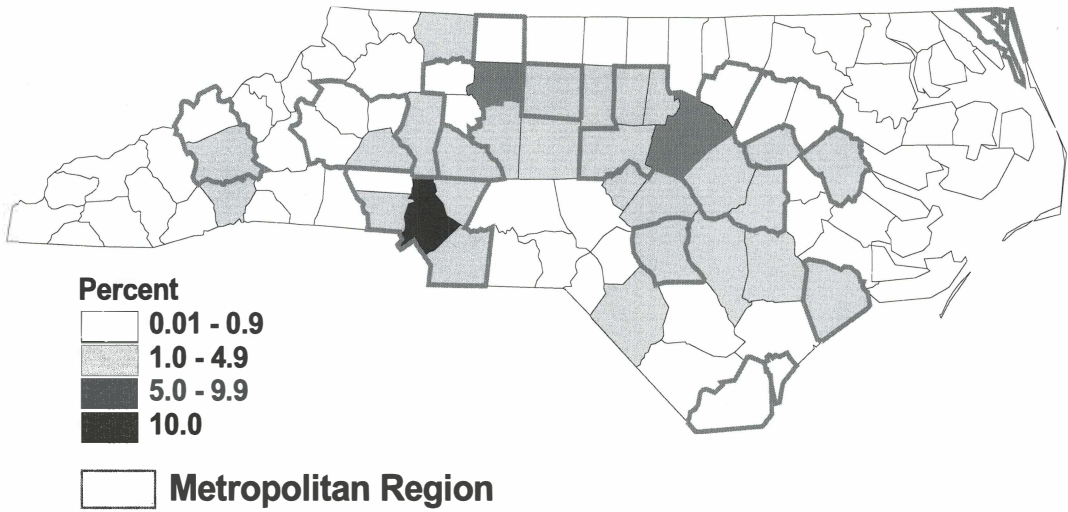


Figure 3c. Mexicans in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

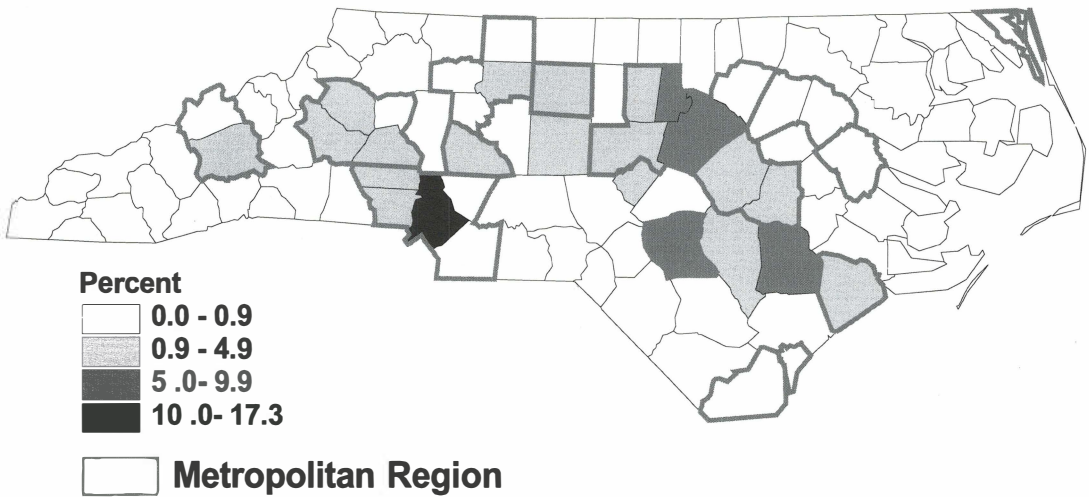


Figure 3d. Central Americans in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

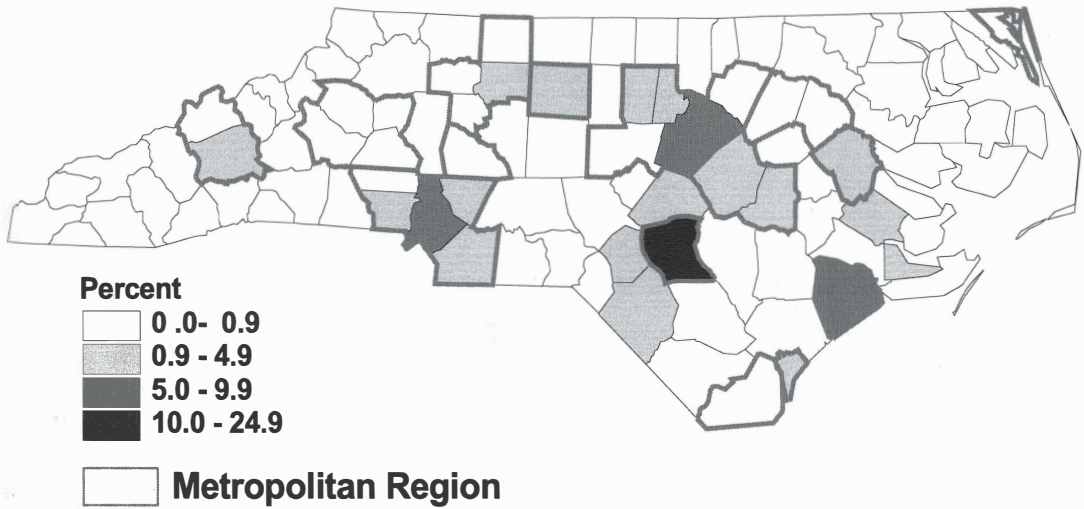


Figure 3e .Puerto Ricans in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

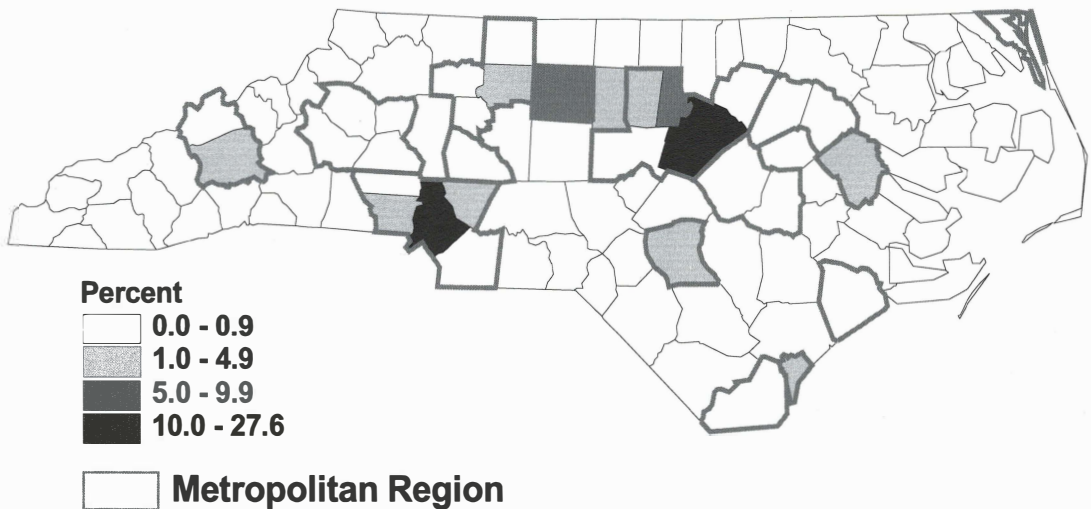


Figure 3f. Asian Indians in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

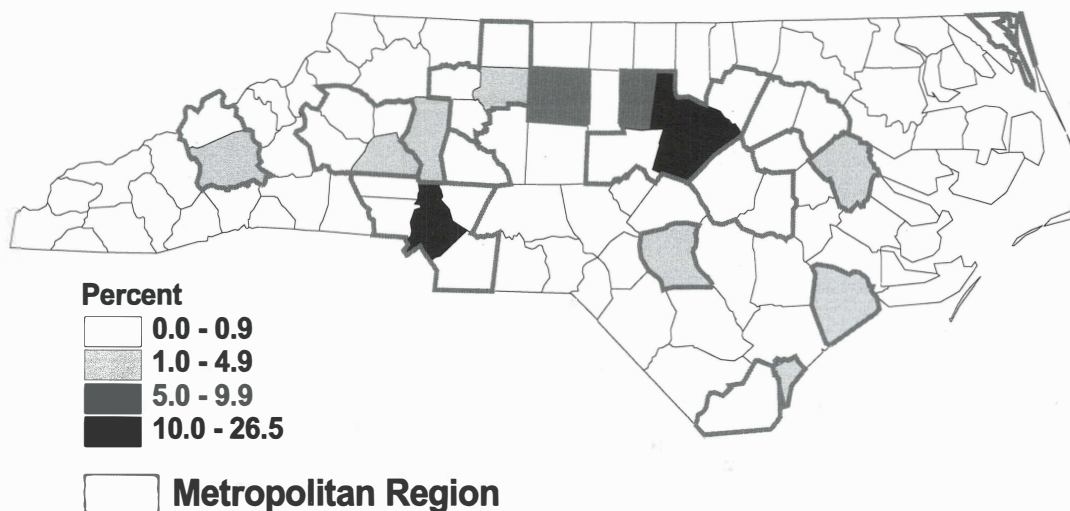


Figure 3g. Chinese in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

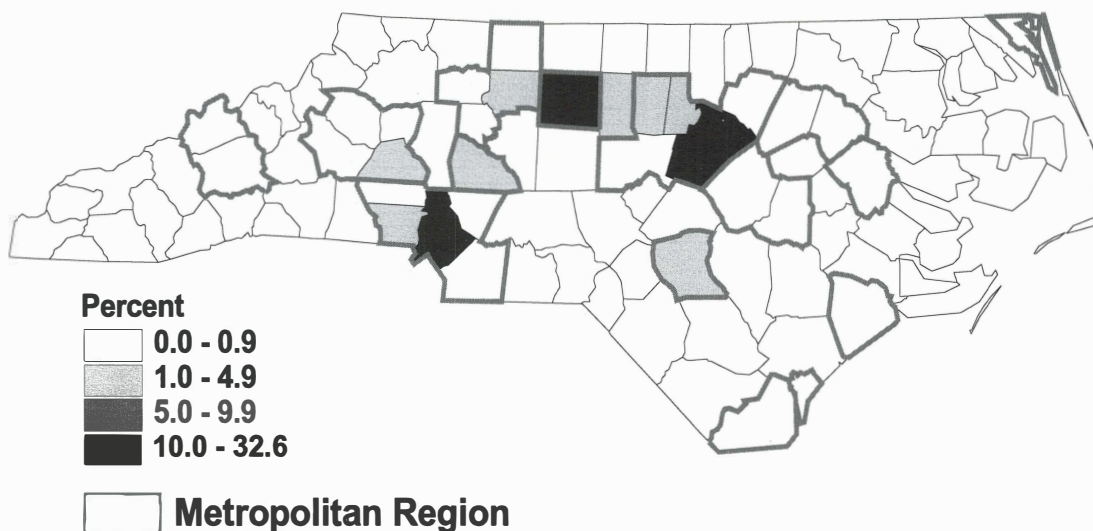


Figure 3g. Vietnamese in North Carolina, 2000. (Source: Summary Tape Files. 2000. North Carolina. U.S. Bureau of the Census.)

Table 1. Percentage Distribution of Ethnic/Racial Groups in Metropolitan Regions of North Carolina, 2000.

Racial/Ethnic Group	All NC Regions	Charlotte	Raleigh-Durham-Chapel Hill
Non-Hispanic white	61.8	16.6	14.0
Non-Hispanic black	63.8	15.9	15.5
Mexican	63.9	18.1	18.4
Central American	77.2	25.6	22.8
Puerto Rican	78.8	14.6	13.3
Asian Indian	88.0	25.1	42.3
Chinese	89.0	19.3	48.0
Vietnamese	91.5	38.2	20.9

Source: Summary Tape Files 3. North Carolina. 1990 and 2000. U.S. Bureau of the Census.

Table 2. Educational Levels of Ethnic/Racial Groups in the U.S., 2000 (Age 25+).

Ethnic/Racial Group	Percent Less than High School	Percent Bachelor Degree or More
Non-Hispanic white	14.5	27.0
Non-Hispanic black	27.7	14.3
Mexican	46.8	7.5
Central American	44.5	9.5
Puerto Rican	24.2	12.5
Asian Indian	13.3	63.9
Chinese	23.0	48.1
Vietnamese	38.1	19.4

Source: Special Reports Asians and Hispanics. U.S. Bureau of the Census; and Summary Tape Files 3. United States. 2000. U.S. Bureau of the Census.

settle where they had the best opportunity to pursue their livelihoods, and where their set of human capital skills would most appropriately match that of the occupational structure of the destination. It is therefore expected that these groups will exhibit different settlement patterns within North Carolina in response to the types of employment and educational opportunities available in different counties (Figures 3c-3h).

Hispanics: The most striking aspect of North Carolina's Mexican-origin population is that it was much more widely dispersed than the other immigrant groups in the study. The Mexican population was equally distributed between Raleigh-Durham-Chapel Hill (18.4 percent of total Mexicans in North Carolina) and the Charlotte Metropolitan Region (18.1 percent of total Mexicans within North Carolina), but was only slightly larger in these two regions than the non-Hispanic white and black populations were. Given the low educational levels of Mexicans (46.8 percent without high school diplomas), it is not likely that Mexicans are employed in professions or are attending universities in these metropolitan areas. However, the rapid growth of these metropolitan areas requires a large influx of individuals to work in the service sector of the economy. For example, Johnston-Webb (2002) noted that employers in Charlotte have relied upon Mexican workers to fill positions in fast-food restaurants, which requires little investment in education.

An examination of Figure 3c shows that Mexicans are widely dispersed throughout the Piedmont and Coastal Plain. This distribution is likely associated with employment opportunities in agricultural production, textile manufacturing, or meat-processing plants. North Carolina, the nation's major textile employer (Rees, 1996), depends on a labor force willing to accept the low wages. This has allowed this industry to be competitive in the global economy and has created an employment niche for Mexicans. North Carolina has also established itself as one of the most important poultry-processing states, and has used Mexicans and other minorities to supply its labor force (Kandel and Parrado, 2004; Skaggs, Tomaskavic-Devey, and Leiter 2001).

Central Americans are more concentrated than

their Mexican counterparts in the Charlotte Metropolitan Region (25.6 percent of total Central American population within North Carolina) and the Raleigh-Durham-Chapel Hill Metropolitan Region (22.8 percent of total Central Americans within North Carolina). As relative newcomers to the U.S., Central Americans would be likely to seek ethnic enclaves in the larger cities that provide access to employment, housing, and social contacts. Although, when compared to their Central American counterparts, the rates of Mexican immigrants residing in the two largest cities were smaller, the large number of Mexicans provides an additional Hispanic ethnic base that tends to attract Central Americans.

Figure 3d shows the clustering of Central Americans in the Hickory-Morganton-Lenoir and Fayetteville Metropolitan Regions (+5.0 percent each of North Carolina's Central American population). The Hickory Metropolitan Region is noted as an agricultural region, which through a process of chain migration has attracted additional Central Americans (Fink, 2003). Chain migration occurs when information concerning a particular migrant destination is relayed to the origin and thus stimulates additional migrants. Although less likely than their Mexican counterparts to reside in non-metropolitan counties, a fairly high percentage (+5.0) of North Carolina's Central American population was found in Duplin and Lee Counties. These are agricultural counties that need labor for meat-processing facilities. The low educational levels of Central Americans (44.5 percent without high school diplomas) attract them to these jobs (Kandel and Parrado, 2004; Dinnerstein, Nichols, and Reimers, 2003).

Only 14.6 percent of North Carolina's Puerto Rican population resided in the Charlotte Metropolitan Region while 13.3 percent resided in the Raleigh-Durham-Metropolitan Region, indicating that Puerto Ricans are neither highly-skilled individuals seeking professional employment nor low-skilled individuals seeking employment in the service or agricultural sectors. Puerto Ricans are overwhelmingly distributed in counties with military bases (Cumberland, 24.9 percent of North Carolina's Puerto Rican population). An examination of Figure 3e shows that the Puerto Rican population clusters around metropoli-

tan areas but that its representation within the two largest metropolitan regions is less than that of the other Hispanic groups and significantly less than that of the Asian groups. Although Puerto Ricans have educational levels that are far below those of non-Hispanic whites, their status as U.S. citizens makes them eligible for military service which has long been adopted as a strategy for Puerto Ricans to improve their human capital skills. Also, the migration of middle-class Puerto Ricans into the South in the past few decades suggests that North Carolina's Puerto Ricans have attained more human capital than Puerto Ricans in other U.S. regions (Acosta-Bien and Santiago, 2006; Baker 2002).

Asians: Contrary to the dispersed distribution of Asian Indians in the U.S. in general (Kibria, 2006), Asian Indians are one of the most spatially concentrated populations in North Carolina (See Figure 3f). The high concentration of Asian Indians in the Raleigh-Durham-Chapel Hill Region (42.3 percent) is indicative of the very high human capital skills that these individuals possess whether engaged in professions or attending universities (Roseman, 2002). Asian Indians have educational levels that exceed that of any of the other populations examined in this analysis (63.9 percent with a bachelor's degree or better). An additional advantage is that Asian Indians have a greater command of the English language given the history of British dominance in India and are likely more competitive in the labor force than ethnic groups with limited English language skills (Sheth, 1995). Another 25.1 percent of North Carolina's Asian Indian population resides and works in the Charlotte Metropolitan Region. Because Charlotte's economic base is more diversified than that of the Research Triangle Region, it provides a large number of professional opportunities, especially in the business sector. The high concentration of Asian Indians in Guilford County (7.3 percent) is a result of the universities in the county which include the University of North Carolina at Greensboro and North Carolina Agricultural and Technical University.

The Chinese have been settled in the South longer than other Asian groups (Brown and Pannell, 2000), although they are less dispersed. The Chinese

have the highest concentration of all groups with 48.0 percent in Raleigh-Durham-Chapel Hill, while a further 19.3 percent reside and work in Charlotte. Chinese immigrants to the United States come from a broader spectrum of social and economic classes (Teng, 2003; Wong, 2006) than the other Asian groups. While 48.1 percent of Chinese in the U.S. had at least a bachelor's degree, 23.0 percent did not have a high school diploma. The high concentration in Raleigh-Durham-Chapel Hill may indicate that much of the Chinese immigration to North Carolina is recent and composed of professionals. In addition, since the 1980s, many more students from China have come to the U.S. for educational opportunities (Reimers, 2005), and in North Carolina, the bulk of these educational opportunities are found in the Charlotte and Raleigh Metropolitan Regions.

Unlike their Indian and Chinese counterparts, Vietnamese are twice as likely to be in the Charlotte Metropolitan Region (38.2 percent) as in the Raleigh-Durham-Chapel Hill Metropolitan Region (20.9 percent). Only 19.4 percent of Vietnamese in the U.S. have a bachelor's degree, while 38.1 percent have less than a high school diploma. Refugees from Vietnam settled in Charlotte as early as the 1960s and this accounts for their present high concentration in this area. The lower educational level of the Vietnamese in comparison to Indians and Chinese likely explains the lower percentage of North Carolina's Vietnamese population that is located in the Raleigh Metropolitan Region. Guilford County was the location of 19.3 percent of North Carolina's Vietnamese population and was a former refugee settlement locale (Desbarats, 1985).

Although the Vietnamese human capital skills are lower than those of the Indians and Chinese, they exceed those of the Mexicans and Central Americans. When Vietnamese refugees were settled in the U.S. in the 1970s, they were welcomed into host communities throughout the U.S. Although the first waves of Vietnamese refugees were highly skilled, successive waves possessed less human capital (Caplan, Whitmore, and Choy, 1992). In many small towns and rural areas, Vietnamese were employed in low-wage, low-skilled occupations such as meat-processing (Broadway, 1995). After exposure

to life in the United States, some Vietnamese may have moved from smaller communities in the South in pursuit of better opportunities. Although initially hindered by their refugee status, Vietnamese were willing to work in unattractive jobs to provide better opportunities for their children (Do, 1999). By 2000, a generation or two of Vietnamese had grown up in the United States and were less willing than their parents had been to labor in low-wage jobs. In addition they had received an American education and become proficient in English, which improved their human capital skills and allowed them more economic mobility (Zhou, 2001).

Conclusion

This study provides only a rough estimate of the characteristics that draw different Hispanic and Asian groups to certain counties in North Carolina. One additional avenue of research would include an examination of ethnic/racial group settlement patterns based on the percentage of each group that is immigrant versus native stock. This is important because recent immigrants require a period of adjustment to the host country and to find their place in the American labor force, and are likely to display different distributional patterns than their U.S.-born counterparts. A second avenue of research should focus on the demographic and economic characteristics of different racial/ethnic groups by county. Unfortunately these data are not available from the U.S. Census at the county level. Gender ratios, age structure, and educational level of each of the ethnic/racial groups are just a few pertinent pieces of information that require further study. A third direction for future research would be to disaggregate ethnic/racial groups by suburban and central city residence which would likely show much different levels of concentration or dispersion of the groups than at the county scale.

The major difference between the reference populations of non-Hispanic whites and blacks with the six ethnic/racial groups is that the reference groups displayed a less concentrated population than the other groups examined. This is particularly ap-

parent in the Charlotte and Raleigh Metropolitan Regions. The long-residency time of non-Hispanic whites and non-Hispanic blacks within the United States contributes greatly to this distribution. Immigrant flows from Europe no longer comprise the majority of immigrants to the U.S., while lack of major flows of non-Hispanic blacks from Africa or the Caribbean to North Carolina would explain the relatively low percentage of North Carolina's non-Hispanic blacks residing in urban areas (Massey, 2001). Thus, the higher concentration of Hispanics and Asians in Charlotte and Raleigh in comparison to their non-Hispanic white and non-Hispanic black counterparts may parallel on a micro-scale the macro-scale (or national) roles of New York and Los Angeles, where many immigrants settle and then disperse to cities less noted as immigrant gateways after a period of time. Newcomers to a country find that urban areas contain ethnic/racial enclaves that provide a filter in which certain segments of the host society can penetrate (Allen and Turner, 2006).

Theories of migration and its relationship to human capital were explored to explain why immigrants to the United States from Asia had higher educational levels (human capital) than their counterparts from Latin America. Specifically, Borjas (1989) claimed that Asian immigrants were positively selected (higher levels of human capital) while Latin American immigrants were negatively selected. Distance was determined to be the critical factor in this relationship and can be used as a proxy for costs of the move. The further the distance between two locales, the more costly the migration decision and thus less interaction is likely to occur. The aforementioned explains the selectivity of immigrants in the U.S. in general, but does not address the reasons for the differences in distribution between Asians and Hispanics in North Carolina. The basic assumption in this paper is that Asian and Hispanic groups within North Carolina would be distributed according to the economic structure of particular counties. Thus, it is not surprising that the Asian groups have a greater rate of concentration than the Hispanic groups in Charlotte and Raleigh, given the greater human capital skills acquired by the average Asian, and the employment opportunities for highly-skilled

individuals in these metropolitan areas. Conversely, Mexicans and Central Americans are more likely to be found in higher concentrations in the rural or smaller metropolitan counties than are their Asian counterparts, where they are attracted by employment in agriculture, meat-processing, and other low-wage manufacturing and service opportunities. Puerto Ricans are concentrated in North Carolina counties with military bases.

References

- Acosta-Bien, E. and C.E. Santiago.** 2006. *Puerto Ricans in the United States: A Contemporary Portrait*. Boulder: Lynne Rienner Publishers.
- Allen, J.P. and E. Turner.** 2006. Ethnic Residential Concentrations in United States Metropolitan Areas. *The Geographical Review*. 95 2: 267-285.
- Bailey, R.** 2005. New Immigrant Communities in the North Carolina Piedmont Triad: Integration Issues and Challenges. In *Beyond the Gateway: Immigrants in a Changing America*, ed. E. Gozdiak and S. Forbes Martin, 57-86. Lanham, MD: Lexington Books.
- Baker, S.** 2002. *Understanding Mainland Puerto Rican Poverty*. Philadelphia: Temple University Press.
- Becker, G.S.** 1964. *Human Capital*. Columbia University Press, New York.
- Borjas, G.** 1989. Economic Theory and International Migration. *International Migration Review* 23: 457-85.
- Broadway, M.** 1995. From City to Countryside: Recent Changes in the Structure and Location of the Meat and Fish-Processing Industries. In *Anyway You Cut It: Meat Processing and Small Town America*, ed. D.D. Stull, M.J. Broadway and D. Griffith. Lawrence: University of Kansas.
- Brown, C.L. and C.W. Pannell.** 2000. The Chinese in America. In *Ethnicity in Contemporary America: A Geographical Appraisal*, ed. J.O. McKee, 283-310. Lanham, MD: Rowman and Littlefield Publishers, Inc.
- Bump, M.N.; B.L. Lowell, and S. Petterson.** 2005. The Growth and Population Characteristics of Immigrants and Minorities in America's New Settlement States. In *Beyond the Gateway: Immigrants in a Changing America*, ed. E. Gozdiak and S. Forbes Martin, 19-53. Lanham, MD: Lexington Books.
- Caplan, N, J.K. Whitmore, and M.H. Choy.** 1992. The Boat People and Achievement in America: A Study of Family Life, Hard Work, and Cultural Values. Ann Arbor: University of Michigan Press.
- Desbarats, J.** 1985. IndoChinese Resettlement in the United States. *Annals of the Association of American Geographers*. 75 (4): 522-538.
- Dinnerstein, L., R.L. Nichols, and D.M. Reimers.** 2003. *Natives and Strangers: A Multi-Cultural History of Americans*, 4th Edition. New York: Oakland University Press.
- Do, H.D.** 1999. *The New Americans: The Vietnamese Americans*. Westport, CT: Greenwood Press.
- Duncan, B., V.J. Hotz, and S.J. Trejo.** 2006. Hispanics in the U.S. Labor Market. In *Hispanics and the Future of America*. Edited by M. Tienda and F. Mitchell. The National Academies Press: Washington, D.C.
- Durand, J., E. Telles, and J. Flashman.** 2006. The Demographic Foundations of the Latino Population. In *Hispanics and the Future of America*. Edited by M. Tienda and F. Mitchell. The National Academies Press: Washington, D.C.

- Fink, L.** 2003. *The Maya of Morganton: Work and Community in the Nuevo South*. Chapel Hill, NC: University of North Carolina Press.
- Frazier, J.W.; F.W. Margal; and E. Tettey-Fio.** 2003. *Race and Place: Equity Issues in Urban America*. Boulder, CO: Westview Press.
- Gade, O.** 1996. Economic Development Regions of North Carolina. In *Snapshots of the Carolinas: Landscapes and Cultures*, ed. G. Gordon Bennett, 149-155. Washington, D.C.: Association of American Geographers.
- Gozdiak, E.** 2005. New Immigrant Communities and Integration. In *Beyond the Gateway: Immigrants in a Changing America*, ed. E. Gozdiak and S. Forbes Martin, 3-18. Lanham, MD: Lexington Books.
- Greenwood, M.** 1988. Changing Patterns of Migration and Regional Economic Growth in the U.S.: A Demographic Perspective. *Growth and Change* 19: 68-87.
- Harris, J. and M. Todaro.** 1970. Migration, Unemployment and Development: A Two Sector Analysis. *American Economic Review* 60: 139-49.
- Hartshorn, T.A.** 1997. The Changed South, 1947-1997. *Southeastern Geographer* 37 (2): 122-139.
- Hernandez-Leon, R. and V. Zuniga.** 2000. Making Carpet by the Mile: The Emergence of a Mexican Community in an Industrial Region of the U.S. Historic South. *Social Science Quarterly* 81 (1) 49-66.
- Horowitz, R. and M.J. Miller.** 1999 *Immigrants in the Delmarva Poultry Processing Industry: The Changing Face of Georgetown, Delaware and Environs*. Occasional Paper No. 37. Julian Samora Research Institute.
- Johnson, Jr. J.H., K.D. Johnson-Webb, and W.C. Farrell, Jr.** 1999. *Popular Government*. 65 (1), 2-12.
- Johnson-Webb, K.D.** 2002. Employer Recruitment and Hispanic Labor Migration: North Carolina Urban Areas at the End of the Millennium. *Professional Geographer*. 54 (3): 406-421.
- Kandel, W. and E.A. Parrado.** 2004. Hispanics in the American South and the Transformation of the Poultry Industry. In *Hispanic Spaces, Latino Places: Community and Cultural Diversity in Contemporary America*, ed. D.D. Arreola, 255-276. Austin: University of Texas Press.
- Kibria, N.** 2006. South Asian Americans. In *Asian Americans: Contemporary Trends and Issues*. Second Edition, ed. P.G. Min, 206-227. Thousand Oaks, CA: Pine Forge Press.
- Lee, E.** 1966. A Theory of Migration. *Demography* 3:47-57.
- Massey, D.S.** 2001. The New Immigration and Ethnicity in the United States. In *Interdisciplinary Perspectives on the New Immigration, Vol. 1. Theoretical Perspectives*, ed. M.M. Suarez-Orozco, C. Suarez-Orozco, and D. Qin-Hilliard, 1-22. New York: Routledge.
- Pandit, K.** 1997. The Southern Migration Turn-around and Current Patterns. *Southeastern Geographer*. 37: 238-250.
- Ravenstein, E.G.** 1885. The Laws of Migration. *Journal of the Royal Statistical Society*. 52: 167-227.
- Rees, J.** 1996. Textiles in the Carolinas: Do They Have a Future? In *Snapshots of the Carolinas: Landscapes and Cultures*, ed. G. G. Bennett, 171-174. Washington: Association of American Geographers.
- Ritchey, P.** 1976. Explanations of Migration. *Annual Review of Sociology*. 2: 363-404.
- Reimers, D.M.** 2005. *Other Immigrants: The Global Origins of the American People*. New York: University Press.
- Roseman, C.C.** 2002. The Changing Ethnic Map of the United States. In *Geographical Identities of Ethnic America: Race, Space, and Place*, ed. K.A.

- Berry and M.L. Henderson, 15-37. Reno: University of Nevada Press.
- Sakamoto, A. and Y. Xie.** 2006. The Socioeconomic Attainments of Asian Americans. Pp. 54-77. In *Asian Americans: Contemporary Trends and Issues*. 2nd Edition. Edited by P.G. Min. Thousand Oaks, CA: Pine Forge Press.
- Schmid, C.** 2003. Immigration and Asian and Hispanic Minorities in the New South: An Exploration of History, Attitudes, and Demographic Trends. *Sociological Spectrum* 23: 129-157.
- Schultz, T.W.** 1963. *The Economic Value of Education*. Columbia University Press, New York.
- Shelley, F.M. and G.R. Webster.** 1998. Population, Settlement, Race and Ethnicity in the South. *Journal of Geography* 97: 163-175.
- Sjaastad, L.** 1962. The Costs and Returns of Migration. *The Journal of Political Economy*. 70:80-93.
- Sheth, M.** 1995. Asian Indian Americans. In *Asian Americans: Contemporary Trends and Issues*. Edited by P.G. Min, 169-198. Thousand Oaks, CA: Sage Publications.
- Skaggs, S.D., Tomaskovic-Devey and J. Leiter.** 2001. *Latino/a Employment Growth in North Carolina: Ethnic Displacement or Replacement?* Powerpoint presentation accessed from <http://sasw.chass.ncu.edu/jeff/emplchge.ppt>. on March 19, 2006.
- Teng, B.** 2003. *The Chinese Americans*. Boulder: University Press of Colorado.
- United States Bureau of the Census.** 2004. *We the People: Asians in the United States*. Census 2000 Special Reports.
- United States Bureau of the Census.** 2004. *We the People: Hispanics in the United States*. Census 2000 Special Reports.
- United States Bureau of the Census.** 2000. *Summary Tape Files 1. North Carolina*.
- United States Bureau of the Census.** 1990. *Summary Tape Files 1. North Carolina*.
- United States Department of Labor.** 2006. *Bureau of Labor Statistics. North Carolina*.
- Wong, M.G.** 2006. Chinese Americans. In *Asian Americans: Contemporary Trends and Issues*. Second Edition, ed. P.G. Min, 110-145. Thousand Oaks, CA: Pine Forge Press.
- Zhou, M.** 2001. Straddling Different Worlds: The Acculturation of Vietnamese Refugee Children. In *Ethnicities: Children of Immigrants in America*, ed. R.G. Rumbaut and A. Portes, 187-228. Berkeley, CA: University of California Press.

The Effects of Local Weather Patterns on Nitrate and Sulfate Rainwater Concentrations in Wilmington, North Carolina

Sarah Beth Jenkins
Douglas W. Gamble
Michael M. Benedetti
Joan Willey

University of North Carolina Wilmington

Analysis of weather patterns on a synoptic or regional scale is the common direction of study in air pollution meteorology with few studies analyzing weather conditions proximal to collection sites. A study that focuses on local weather conditions may lead to better understanding and more accurate forecasting of rain water chemistry than synoptic or regional scale studies. The objective of this project is to determine the relationship between local weather patterns and rain water chemistry in Wilmington, NC. Daily and hourly meteorological data (average temperature, relative humidity, wind speed and direction, and maximum and minimum temperatures) were collected for the 48 hour period prior to each rain event. In addition, the nitrate and sulfate concentrations were obtained from the Marine and Atmospheric Chemistry Research Laboratory (MACRL) at UNCW. Data analysis of local weather conditions 48 hours prior to 24 storm events, including review of descriptive statistics, graphical and linear regression analysis, *t*-tests, and synoptic weather map analysis, was completed to determine any relationship between variables. The overall conclusion of the study is that there are no obvious or significant relationships between nitrate and sulfate concentrations and local meteorological variables. However, wind direction frequency and statistical tests suggest that trajectory, whether terrestrial or marine, is the most important factor influencing rain water chemistry.

Introduction

Rainwater chemistry is important because pollutants such as nitrate, sulfate and ammonium (of which, nitrogen and ammonium are nitrogen analytes) can be carried in water released from the atmosphere. NO and NO₂ typically enter the atmosphere through anthropogenic sources such as automobiles and fossil fuel combustion in power plants (Long, 2003; Botkin *et al.*, 1995). The oxidation of NO and NO₂ forms atmospheric nitrate. Sulfate emissions from power plants are oxidized to form sulfuric acid which in turn becomes sulfate. Burn-

ing coal in power plants is the major anthropogenic source of sulfate. However, petroleum refining, the production of paper, cement and aluminum also contribute sulfate (Long, 2003; Botkin *et al.*, 1995).

Large amounts of sulfuric and nitric acid deposition can lead to negative impacts on acid-sensitive ecosystems due to their respective contribution to acidic deposition (Lehmann *et al.*, 2005). In addition, excess nitrogen is one of the most harmful nutrients to plant algal and microbial production, and atmospheric deposition is responsible for 35% to 60% of nitrogen analytes entering coastal waters of

the Atlantic (Kieber *et al.*, 2005). The nitrogen is harmful to these organisms because phytoplankton requires nitrogen to bloom, however, when the concentration of the nutrient is too large, the blooms become too numerous. As a result, the overabundance of phytoplankton is not completely consumed by the organisms that feed on them and are left to die or be decomposed by bacteria. The bacteria consume large amounts of oxygen during decomposition and deplete the surrounding waters of much needed oxygen. Decreased amounts of oxygen lead to hypoxia (reduced amounts of oxygen) and anoxia (a complete absence of oxygen). These conditions can potentially lead to toxic algal blooms, changes in types of phytoplankton populations and higher occurrences of fish and shell-fish disease (Russell *et al.*, 1998).

Research has linked the occurrence of pollutants in rainwater with specific weather patterns in order to gain a better understanding of how weather may diminish or exacerbate pollution levels (Russell *et al.*, 1998; Walker *et al.* 2000; Dayan & Lamb, 2003; Hewitt *et al.*, 2003). Such research explores how storm path and trajectory, storm type, circulation around a storm, geographic location, seasonality, and precipitation amount affect pollutants found in rainwater. One example of this research, which focused on the Chesapeake Bay region, classified storm trajectories and their associated pollutants into five different groups: westerly, easterly, northwesterly, southwesterly and southerly (Russell *et al.*, 1998). Analysis indicated that easterly trajectories were characterized by the lowest amount of nitrogen because these air masses traveled over the Atlantic Ocean. The southerly trajectory was associated with high concentrations of nitrate. Further, this study indicated that source region information can be used to determine how much nitrogen is deposited through the atmosphere, what processes produce the nitrogen, and also where the nitrogen originated. Air masses that travel over heavily populated (and therefore, heavily traveled) areas may pick up nitrogen analytes from anthropogenic emissions. The Chesapeake Bay study also showed that NO_x (the collective term for NO and NO_2) emissions from combustion sources are the main source of nitrate in

atmospheric deposition. This is the reason that storms that originate over land tend to have higher concentrations of analytes than the storms that originate over water.

It is common in such research (Dayan and Lamb, 2003; Russell *et al.*, 1998; and Walker *et al.*, 2000) to consider a seasonal aspect of the atmospheric chemistry. Results from seasonal analysis indicate that high nitrate and ammonium concentrations occur during the spring, early summer and winter months. The spring/early summer high concentrations can be attributed to the increase in soil fertilizers and animal waste emissions associated with planting in the spring while the winter highs can be attributed to increased fuel emissions (Russell *et al.*, 1998). Seasonality is also a factor in synoptic scale meteorology. Changes in mean seasonal patterns in upper air flow can cause fluctuations in the ammonium concentrations (Walker *et al.*, 2000).

These studies (Dayan and Lamb, 2003; Russell *et al.*, 1998; and Walker *et al.*, 2000) also indicate that the amount of precipitation is a factor that affects concentrations of nitrogen analytes in atmospheric deposition. The term "washout" is used in many studies to explain why there seems to be smaller concentrations of analytes when precipitation amounts are larger. High amounts of water dilute the concentration of the pollutant.

The overall conclusion of these studies is that rainwater chemistry is highly variable and more research needs to be completed in order to better understand what the future may bring concerning the impact of rainwater pollution on animal, aquatic and possibly human populations. Identification of pollution sources, transport characteristics and predicted concentrations may lead to physical or chemical controls used for the development of sound environmental management policies to prevent future damage to sensitive aquatic and terrestrial ecosystem (Walker *et al.*, 2000).

While such results are helpful, a more in depth analysis of local weather conditions associated with the local rain water chemistry is needed. Previous studies have found regional variation in trends of atmospheric chemistry across the United States. For instance, Lehmann *et al.* (2005) found in the west

central United States there were significant nitrate increases while in the northeastern United States there were significant decreases. Further, significant dissolved inorganic nitrogen decreases were observed in the northeastern United States while elsewhere there were significant increases. Such spatial variability underscores the need to combine knowledge of regional meteorology with knowledge of atmospheric chemistry to better understand air pollution dynamics. The majority of previous research has completed analysis of weather patterns on a synoptic scale with few studies analyzing weather conditions proximal to collection sites. A study that focuses on local weather conditions may lead to better understanding and more accurate forecasting of rain water chemistry. Such information may prove to be very important given the potential for error in synoptic scale trajectory analysis and when pollution sources are near the collection sites. Therefore, the study described here is of particular importance because it will further research local scale processes in air pollution dynamics. Accordingly, the purpose of this study is to determine the relationship between local weather patterns and nitrate and sulfate rain water chemistry in Wilmington, NC.

Wilmington, North Carolina is characterized by frequent and ample rainfall throughout the year; however, summer usually has higher amounts of rainfall. Thunderstorms are the main source for summer rainfall. These thunderstorms are usually short in duration but rainfall is heavy and unevenly distributed across the area. Slow, steady rain is common in the winter months and is associated with slow-moving, low-pressure systems, usually staying in the area one or two days (Garooogian, 2000)

In a study of rainfall chemistry in Wilmington, the Marine and Atmospheric Chemistry Research Laboratory (MACRL) at UNCW has monitored the rainwater chemistry of 129 precipitation events between February 2002 and August 2003. This research includes chemical analysis for ammonium, nitrate, organic nitrogen and free amino acids concentrations in rain water and correlates these concentrations with atmospheric trajectories of the storms producing rain (Long, 2003; Kieber *et al.*, 2005). The trajectories of the storms were classified as terrestrial, oceanic or

mixed. Their analysis indicates that terrestrial storms are associated with significant values of all chemicals except organic nitrogen. Oceanic storms were associated with low concentrations of all chemicals, especially ammonium. The results suggest that for the Wilmington, NC area, storms that have a terrestrial origin have high concentrations of nitrogen analytes, suggesting the influence of swine production, while storms of oceanic origin are characterized by low concentrations of nitrogen analytes. In addition, the Wilmington, NC area also has highs of ammonium in the spring and summer and high nitrate amounts in the winter months. This analysis did not examine the local weather conditions associated with rainfall events.

The overall objective of this project is to determine the relationship between local weather patterns and rain water chemistry in Wilmington, NC. Specific objectives to be completed in this study include:

1. Compare local weather conditions for 12 winter and 12 summer rain events identified in the MACRL database by trajectory, season, storm type and nitrate and sulfate concentration.
2. Determine if a relationship exists between local weather conditions and nitrate and sulfate concentration in precipitation.
3. Determine if a statistical difference exists in local weather conditions and nitrate and sulfate concentration by season and trajectory.
4. Determine the type of storm systems preceding rain events and compare nitrate and sulfate concentration by storm type.

Methodology

Daily and hourly meteorological data were collected from the Wilmington, North Carolina National Weather Service (NWS) Office web page (<http://www.erh.noaa.gov/er/ilm/>) and the Plymouth State Weather Center 24 HR Surface Station Summary Generator web page (<http://vortex.plymouth.edu/statlog-u.html>) for the Wilmington, NC weather station (Figure 1). This data consisted of average temperature, relative humidity, wind speed and direction, and maximum and

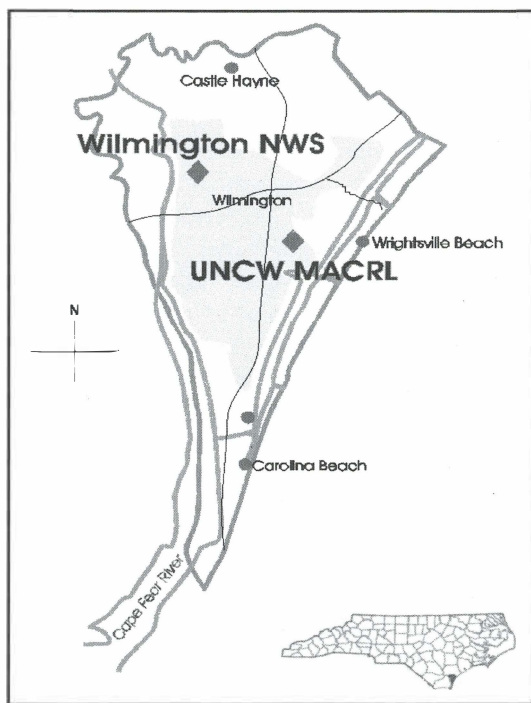


Figure 1. Map of New Hanover County indicating location of the two collection sites referenced in this study.

minimum temperatures for the 48 hour period prior to each rain event. This data, along with the nitrate and sulfate concentrations obtained from the MACRL Lab at UNCW (Figure 1), were entered into an Excel spreadsheet. Descriptive statistics, specifically mean and standard deviation, were calculated for each variable in order to determine difference and similarities in atmospheric conditions before a rain event by season, trajectory, and chemical concentration. Three histograms were constructed illustrating wind direction, one with all storms included, another showing only marine trajectory storms and the third, illustrating terrestrial storms only. Scatter plots were constructed, plotting each variable against nitrate and sulfate amounts. Trend lines were fit to the scatter plot through linear regression to describe the relationship between variables. The trend lines are intended to describe relationships as opposed to predictive models. Tables listing the maximum, minimum and 48 hour average

of each local meteorological variable and chemical by marine vs. terrestrial trajectory and summer vs. winter were constructed. Statistical *t*-tests (two-sample, two-tailed tests assuming equal variance) were completed for each variable and chemical concentration comparing the mean values of two seasonal and trajectory samples (summer vs. winter and marine vs. terrestrial trajectory). The *t*-test was used to determine if a statistically significant difference in variables existed before a rain event by season and trajectory. Finally, NOAA daily weather maps were used to determine synoptic scale weather conditions 48 hours before rain events. Chemical concentration was then compared by storm type. Statistical tests to determine statistically significant difference could not be performed on data by storm type given the small sample size for each storm type.

Results and Discussion

A review of histograms reveals that the most frequent wind direction preceding storm events is from the East-Northeast (Figure 2). The most frequent wind direction preceding a storm associated with marine trajectory storms was East-Northeast (Figure 3). The most common wind direction preceding a terrestrial trajectory storm was South-Southwest (Figure 4). All trend lines fitted to scatter plots indicate a positive relationship between local meteorological values and nitrate and sulfate concentrations except for the scatter plots plotting the chemicals nitrate and sulfate against precipitation (Table 1). Such a relationship suggests that as temperature, relative humidity, and wind speed increase so does sulfate and nitrate concentrations. The scatter plots between precipitation amount and both nitrate and sulfate indicate a negative relationship. Trend lines fitted to scatter plots indicate a negative relationship between precipitation amount and nitrate and sulfate concentration. All of the linear regressions are poor models with all r^2 values for all models below 0.1 (Table 1), indicating that meteorological variables explain a low amount of variance in sulfate and nitrate concentrations. The precipitation models are the only models with a slope significantly different from zero, suggesting a "washout" effect may be present in Wilmington.

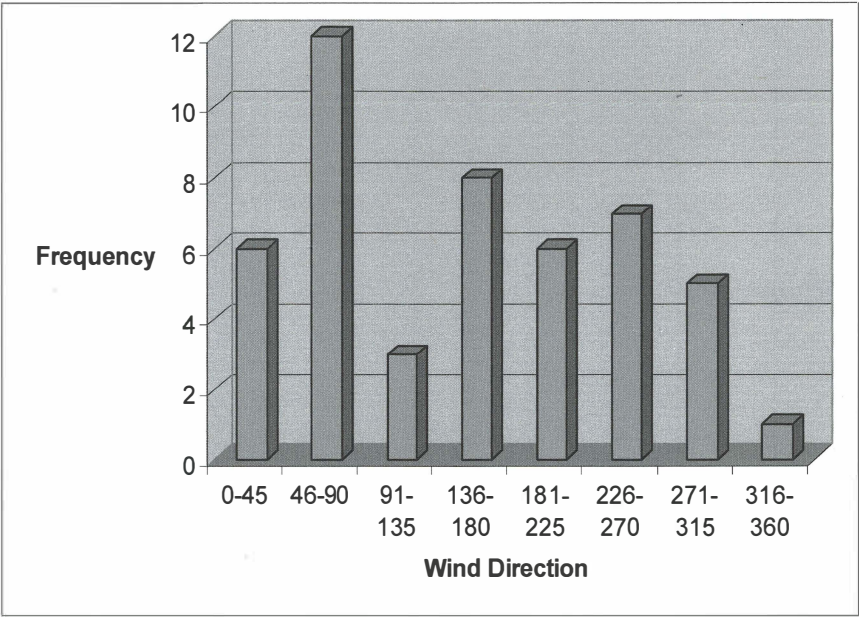


Figure 2. Wind direction histogram displaying frequency of wind direction for all 24 storm events from August 25, 2003 to June 29, 2005 in Wilmington, NC.

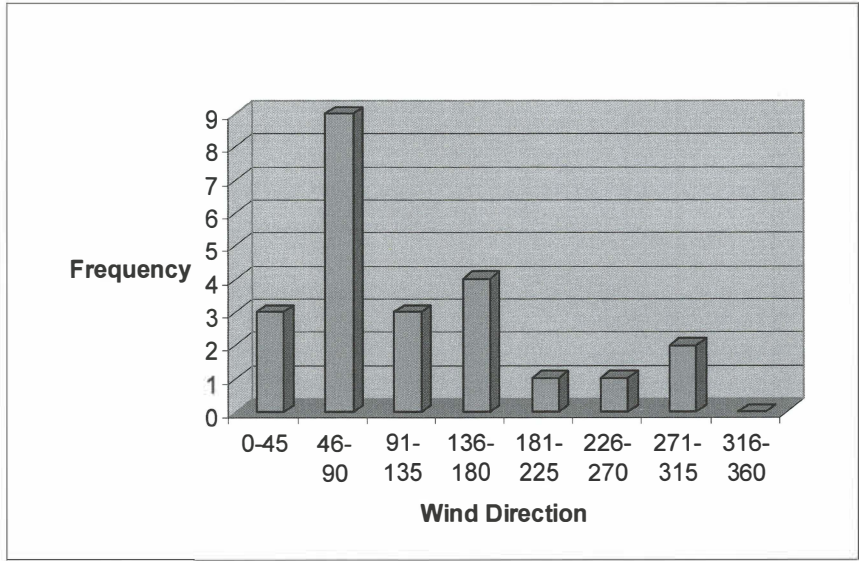


Figure 3. Wind direction histogram displaying frequency of wind direction for marine trajectory storms from August 25, 2002 to June 29, 2005 in Wilmington, NC.

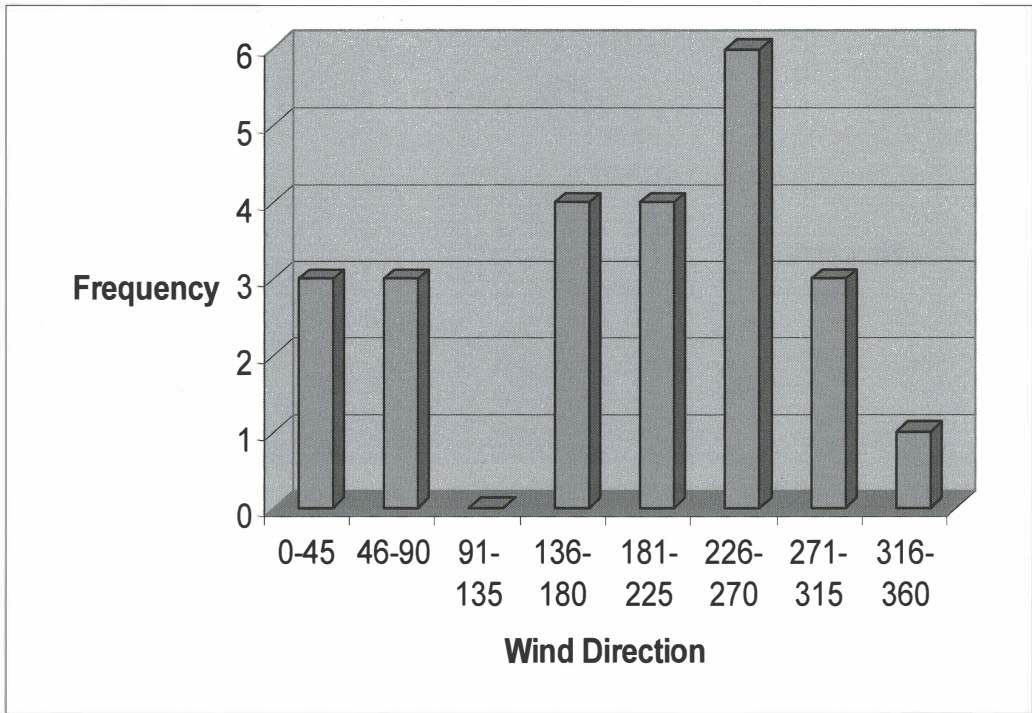


Figure 4. Wind direction histogram displaying frequency of wind direction from terrestrial trajectory storms from August 25, 2002 to June 29, 2005 in Wilmington, NC.

Table 1. Summary of scatter plot trend line slopes and r^2 for 24 rain events from August 25, 2002 to June 29, 2005 in Wilmington, NC.

<i>Scatter Plot</i>	<i>Slope</i>	<i>r² Value</i>	<i>p Value</i>
Nitrate and Average Temperature	0.3132	0.0579	0.85
Nitrate and Average Wind Speed	0.9565	0.0214	0.39
Nitrate and Relative Humidity	22.3370	0.0761	0.78
Nitrate and Precipitation	-0.4017	0.2136	0.02
Sulfate and Average Temperature	0.0792	0.0072	0.39
Sulfate and Average Wind Speed	0.8241	0.0311	0.19
Sulfate and Relative Humidity	6.5988	0.0133	0.12
Sulfate and Precipitation	-0.3000	0.2330	0.02

Based on this analysis, the most striking result is the frequency of local surface wind direction associated with marine and terrestrial trajectories. It is clear that different wind directions dominate each of the trajectory types. The most frequent directions are consistent with trajectory descriptions in that local surface winds associated with a terrestrial trajectory will come from the SSW across the southeastern United States land surface, and that local winds associated with a marine trajectory are ENE, originating and traveling across open water. Unfortunately, it is difficult to compare chemical concentrations by wind direction through a box plot or statistical tests due to the high variability in wind directions and low number of observations for specific wind directions. Beyond wind direction, scatter plots and regression analysis do not indicate any obvious relationships between local meteorological variables and nitrate and sulfate concentrations.

The hypothesis tested in each *t*-test represents an attempt to detect a significant difference in the mean of two populations by season and trajectory, two factors identified in previous research as significant in the relationship between weather conditions and precipitation chemistry. Specifically, the *t*-tests compare the meteorological variables temperature, wind speed, relative humidity and precipitation by season and trajectory (Table 2). The *t*-tests indicate no significant difference in variable by season or trajectory except for a significant differences in temperature and precipitation (precipitation terrestrial mean 15 mm, precipitation marine mean 25 mm; precipitation summer mean 24mm, precipitation winter mean 15 mm) between summer and winter (summer mean temperature 77.3°F, winter mean temperature 53.1°F) (Table 2). Such a result is expected and not surprising given the annual temperature range of Wilmington, NC and the different air masses that dominate the region during these two seasons and by trajectory.

In terms of concentrations of nitrates and sulfates by precipitation amount, there was no significant difference in either nitrate or sulfate concentrations when comparing levels between winter and summer (Table 2). In terms of comparison of nitrate and sulfate concentrations by trajectory type,

nitrate levels are not significantly different for marine or terrestrial storms (Table 2). However, there is a significant difference in sulfate concentrations between marine (11.7iM) and terrestrial trajectories (22.0iM) with terrestrial concentrations double marine concentrations. This statistically significant difference between marine and terrestrial sulfate concentrations may be directly associated with point source industrial pollution only existing over land. The high amounts of precipitation in marine storms may dilute sulfate concentrations.

Analysis of NOAA daily weather maps revealed that the most common storm system occurring during the 48 hours prior to the storm event was equally divided between Cold Fronts and Stationary Fronts (Table 3). Review of the direction that these frontal storms travel indicates that the systems travel most frequently from the west to east (7) or northwest to southeast (3) (Table 3). In addition to these directions, systems occasionally travel from north to south, south to north, or northwest to southeast (Table 3). A comparison of nitrate concentrations levels across storm types indicates that Cold Front storms have the highest mean nitrate concentration (27.91uM). However, this high mean value may be due to one anomalous storm on 6/17/2003, 67.9 micromolar concentration. When this value is removed from the sample, the mean value drops to 21.2 uM, a value closer to the range of the other storm types. Using this adjusted mean value, Cold Front nitrate concentrations are still greater than other storm types. Backside Flow of High Pressure is the lowest concentration of the other storm types (Table 3). In terms of sulfate concentration, Cold Fronts have the greatest mean concentration and Backside Flow of High Pressure has the lowest mean concentration (Table 3). Given the small sample size of storm types, statistical tests cannot be completed to determine if these differences are statistically significant. Since, a west to east track dominates Cold Front storms, and a Northeasterly track dominates the Backside Flow around a High, it appears that the difference in nitrate and sulfate concentrations is again linked to air mass travel over land-based point-sources and high precipitation amounts for marine storms. A separation of storm events into marine

Table 2. Summary of *t*-test statistic hypothesis testing of local meteorological variables and sulfate and nitrate variables.

<i>Test</i>	<i>t-value</i>	<i>p-value</i>	<i>df</i>	<i>Significant?</i>
Marine vs. Terrestrial Sulfate	2.070	0.049	22	yes
Marine vs. Terrestrial Temperature	0.060	>0.623	22	no
Marine vs. Terrestrial Nitrate	1.020	0.329	22	no
Marine vs. Terrestrial Wind Direction	2.600	0.017	22	no
Marine vs. Terrestrial Relative Humidity	0.034	>0.623	22	no
Marine vs. Terrestrial Wind Speed	0.370	>0.623	22	no
Marine vs. Terrestrial Precipitation	4.110	0.001	22	yes
Summer vs. Winter Sulfate	0.060	>0.623	22	no
Summer vs. Winter Temperature	8.060	<0.000	22	yes
Summer vs. Winter Nitrate	0.250	>0.623	22	no
Summer vs. Winter Wind Direction	0.720	0.492	22	no
Summer vs. Winter Relative Humidity	0.330	>0.623	22	no
Summer vs. Winter Wind Speed	0.500	0.623	22	no
Summer vs. Winter Precipitation	4.200	0.001	22	yes

and terrestrial trajectory types indicates that Cold Front and Stationary Front storms dominate terrestrial trajectories, and Backside High Pressure Flow and Stationary Front storms dominate the marine trajectory. These frequencies further support the hypothesis that high chemical concentration exist for trajectories over land and low concentrations for trajectories over water (Table 3).

Conclusions

The purpose of this study was to determine the relationship between local weather patterns and nitrate and sulfate concentrations in rain water at Wilmington, North Carolina. Data analysis of local weather conditions 48 hours prior to 24 storm events, including review of descriptive statistics, graphical and linear regression analysis, *t*-tests, and synoptic weather map analysis, was completed to determine any relationship between variables. The overall conclusion of the study is that there are no obvious relationships between nitrate and sulfate concentrations and local meteorological variables. Instead, wind direction frequency and statistical tests suggest that trajectory, whether terrestrial or marine, is the most important factor influencing rain water chemistry. Further, weather map analysis indicated

terrestrial storms, such as Cold Fronts, have higher amounts of nitrate and sulfate while marine storms are characterized by lower concentrations of the chemicals. In conclusion, this study indicates that storm track is the most important factor influencing nitrate and sulfate concentration in the Wilmington, NC area while local weather conditions may not add significant additional information to existing knowledge based upon trajectory analysis.

References

- Beverland, I.J., Crowther, J.M., Srinivas, M.S.N. and Heal, M.R. 1998. The Influence of Meteorology and Atmospheric Transport Patterns on the Chemical Composition of Rainfall in South-east England, *Atmospheric Environment*, V. 32, No. 6, 1039-1048
- Botkin, D.B., Keller, E.A., 1995. Environmental Science: Earth as a Living Planet, John Wiley & Sons, Inc., New York: pp. 453
- Dayan, U. and Lamb, D. 2003. Meteorological Indicators of Summer Precipitation Chemistry in Central Pennsylvania, *Atmospheric Environment*, V.

Table 3. Summary of synoptic storm type data for the 24 rain events included in this analysis. Chemical concentrations provided in micromolars.

<i>Dates</i>	<i>Storm Type</i>	<i>Rain (mm)</i>	<i>NO₃⁻</i>	<i>SO₄²⁻</i>
1/14/05 marine	Backside H, NE	24	0.5	5.5
11/10/02 marine	Backside H, NE	2	0.2	6.2
6/29/2005 marine	Backside H, NE	39	1.3	3.0
7/14/03 marine	Backside H, NE	2	3.4	2.8
<i>Aggregate</i>		17	1.4	4.4
6/17/03 marine	Cold Front, N-S	3	67.8	38.2
12/4/02 terrestrial	Cold Front, NW-SE	10	41.0	42.9
2/11/03 terrestrial	Cold Front, NW-SE	13	11.8	16.4
12/14/02 terrestrial	Cold Front, W-E	31	10.4	10.8
5/24/05 terrestrial	Cold Front, W-E	13	20.5	41.0
7/12/03 terrestrial	Cold Front, W-E	5	42.9	28.4
12/11/03 marine	Cold Front, W-E	11.4	1.0	6.6
<i>Aggregate</i>		12	27.9	26.3
2/14/04 terrestrial	Frontside H	18	5.3	7.7
2/27/04 marine	Low	30	4.7	9.7
8/8/03 terrestrial	Stationary Front, NW-SE	22	4.1	4.2
10/11/02 marine	Stationary Front, SW-NE	4	40.4	27.7
12/9/04 terrestrial	Stationary Front, W-E	4	44.3	36.9
7/17/04 terrestrial	Stationary Front, W-E	9	22.7	18.3
8/31/02 marine	Stationary Front, W-E	102	2.5	2.2
6/2/05 marine	Stationary Front, S-N	51	4.3	8.2
<i>Aggregate</i>		31.9	19.7	16.2
5/25/05 terrestrial	Trough, L N	14	11.9	16.3
8/25/02 terrestrial	Trough, L N	12	31.3	31.9
6/26/05 marine	Trough, L S	28	1.5	6.1
<i>Aggregate</i>		18	14.9	18.1
12/10/2003 terrestrial	Warm Front, SE-NW	29	1.9	9.5
2/22/2003 marine	Warm Front, SE-NW	8	30.0	24.6
<i>Aggregate</i>		19	15.9	17.0

37, 1045-1055.

Garoogian, D. ed. 2000. *Weather America: A Thirty Year Summary of Statistical Weather and Data and Rankings*. Grey House, Lakeville, CT, pp. 2013.

Hewitt, C.N. and Jackson, A.V. eds., 2003. *Handbook of Atmospheric Science: Principles and Applications*, Blackwell Publishing, Malden, MA, pp. 633.

Kieber, R.J., Long, M.S., and Willey, J.D. 2005. Factors Influencing Nitrogen Speciation in Coastal Rainwater, *Journal of Atmospheric Chemistry*. V. 52, 81-99.

Lehmann, C.M.B, Bowersox, V.C., and Larson, S.M. 2002. Spatial and Temporal Trends of Precipitation Chemistry in the United States, 1985-2002, *Environmental Pollution*. V. 135, 347-361.

Long, M.S., 2003. Atmospheric Deposition in Southeastern North Carolina and its Impact on the Cape Fear Estuary, Master Thesis UNC Wilmington: Wilmington, NC pp.58-59.

Mallin, M.A. 2000. Impacts of Industrial Animal Production on Rivers and Estuaries, *American Scientist*. V. 88, No. 1, 26-37.

Russell, K.M, Galloway, J.N., Macko, S.A., Moody, J.L., and Scudlark, J.R. 1998: Sources of Nitrogen in Wet Deposition to the Chesapeake Bay Region, *Atmospheric Environment*. V. 32, No. 14/15, 2453-2465.

Walker, J.T., Ancja, V.P., and Dickey, D.A. 2000: Atmospheric Transport and Wet Deposition of Ammonium in North Carolina, *Atmospheric Environment*. V. 34, 3407-3418.

Willey, J.D., Kieber, R. J., and Avery, G.B, Jr. 2006: Changing Chemical Composition of Precipitation in Wilmington, North Carolina, U.S.A: Implications for the Continental U.S.A., *Environmental Science & Technology*. V. 40, No. 18, 5675-5680.

Book Review

North Carolina Weather and Climate.

Peter J. Robinson, The University of North Carolina Press, Chapel Hill, North Carolina, 2005. , 256 pp., \$24.95 paper (ISBN 978-0-8078-5625-3) 39.95 cloth (ISBN 978-0-8078-2961-5).

Reviewed by Sol Wuensch, East Carolina University

From the Outer Banks to the Appalachian Mountains, North Carolina exhibits several different climate types. The weather in North Carolina can also vary greatly on both daily and seasonal time scales. North Carolina extends about five hundred miles from east to west, with elevation increasing significantly on the western side of the state. North Carolina consists of eight distinct climate zones, largely due to this increase in elevation across the state. In addition, North Carolina's proximity to the ocean and its mid-latitude position contribute to the variation in weather and climate across the state. One recently published book, entitled *North Carolina Weather and Climate*, examines North Carolina's unique and changeable weather in great detail. Furthermore, the book explains and illustrates climate variations throughout the state. The author, Peter J. Robinson, has been a professor of geography at the University of North Carolina at Chapel Hill since 1971 and has also been working for the State Climate Office since 1996. The book is an excellent source of information for both new residents unfamiliar with North Carolina and those who have lived here for many years. The book is written in such a manner that it is comprehensible to the lay person, but also offers more advanced discussion of complex atmospheric phenomenon. The book remains enlightening whether the reader lives in North Carolina or not, providing information helpful to farmers, home owners, and just about anyone.

The book begins with a foreword by Greg Fishel, chief meteorologist at WRAL-TV in Raleigh, NC. Here Fishel talks about the exciting and changeable nature of North Carolina's weather and his own experiences with this weather since 1981. Beyond

this foreword, the book consists of a preface, seven chapters, four appendices, and a subject index. Chapter One describes the basics of North Carolina weather, explaining the seasonality and causes of particular weather throughout the year. In this chapter, Robinson makes clear the distinction between weather and climate, and also explains some basic ideas of weather forecasting and observation. Chapter Two examines solar radiation across the state and its effect on temperatures and seasonal fluctuations. Chapter Three discusses water in the atmosphere and ground, specifically characteristics of humidity, clouds, precipitation and ground water in regard to North Carolina. Chapter Four describes some of the processes responsible for creating the day to day weather and their seasonal variations in North Carolina. This chapter examines weather patterns across the globe, showing how larger scale weather patterns influence the weather we observe in North Carolina. Chapter Five examines North Carolina's hazardous weather events along with their spatial and seasonal breakdown. In addition, actual historically significant events are highlighted by box discussions, including hurricane, tornado, flood, drought, and even air pollution events. Chapter Six goes into specific detail about the seasonal weather variations for each of North Carolina's three distinct regions: mountain, piedmont, and coastal plain. Some specific reasons for seasonal variations in each region are provided, for example, steep elevation changes in the mountains or proximity to the ocean in the coastal plain. Finally, Chapter Seven explores forecasts and the forecasting of both weather and climate. It also discusses climate change mentioning that while there is significant year-to-year variability,

in North Carolina there has been no discernable trend in the historical record of various meteorological variables.

Appendix A, Getting Information, consists of sources where one can access climate data and includes web addresses, postal addresses, telephone numbers and e-mail addresses of local to global organizations providing climate data. Appendix B is a useful guide to anyone interested in collecting their own weather data. This appendix includes information on appropriate site selection for instruments and an individual discussion of practically all observable weather related phenomenon. Appendix C provides monthly and annual climate information for twenty stations across North Carolina from 1971-2000. Finally, Appendix D is a list of all hurricanes and other tropical systems influencing North Carolina in the twentieth century, including the year, month and date they influenced North Carolina. This appendix includes storm category, name, and description of each storm track. Throughout each chapter there are many maps, pictures, and illustrations which make key concepts easier to understand. Besides these images, numerous graphs and tables also add useful information and allow for the comparison of data across the state. Spread throughout the book is a series of 'box discussions' which depict historic weather events that have affected North Carolina, often with additional maps and tables.

The greatest strengths of this book are the vast amount of information it presents and the style of writing which makes the concepts easily understood, even to individuals unfamiliar with atmospheric science. The information provided is useful to a wide range of people, from the serious farmer to the recreational gardener or even the layperson. Whether living in or far away from North Carolina it is still a good read with plenty of interesting information. Furthermore, the abundance of images that accompany the text significantly increases comprehension and makes the reading more enjoyable. Its maps facilitate understanding of how climate changes spatially across the state and graphs which contain various station data illustrate seasonal changes.

In summary, in the book *North Carolina Weather and Climate*, Peter Robinson provides useful and de-

tailed information about practically all types of meteorological phenomenon and explains how often and where they can be expected in North Carolina. This book is a great read for anyone familiar with North Carolina and especially for someone interested in meteorology or climatology. The success of the book can be measured by its few, if any, weaknesses in the text or presentation of material. The book would make for a great complementary to an introductory weather and climate book for high school or college students in North Carolina. For those interested in North Carolina, this book shows how different our weather and climate is from east to west and how the geography of our state affects the weather and climate. Overall, it an excellent book that I would recommend to anyone interested in weather and climate, and because of the vast diversity of weather observed in North Carolina the book serves as a great educational resource as well.



The Department of Geography and Geology at the University of North Carolina Wilmington offers a Bachelor of Arts degree in Geography. Students who pursue the B.A. degree in geography may choose from a broad, flexible program that meets personal educational goals and interests, including careers and graduate study in physical or human geography, planning or applied geography. The Department of Earth Sciences also offers a certificate in Geographic Information Science (GIS). The certificate enables students to achieve a documented expertise in geographic techniques which can then be leveraged to gain employment in the expanding GIS job market. UNCW Geography also supports a vibrant internship program that places students in a wide variety of professional agencies in southeastern North Carolina.

There are three options of concentration for students in the Geography Program at UNCW:

The **applied geography** option is designed for students who are interested in careers as planners, GIS specialists, and historic preservationists.

The **human geography** option is designed for students who wish to pursue a career as regional specialists, international business officials, and social scientists.

The **physical geography** option is designed for students planning careers as meteorologists, climatologists, geomorphologists, and hydrologists.

Faculty research interests include settlement geography of the South, the urban georgaphy of Moscow, fluvial systems of the Coastal Plain, applied climatology of islands and coasts, GIS applications in watershed management, and the racial landscape of the South. Students are encouraged to participate with faculty in their research and also pursue individual research projects. The geography program makes extensive use of computers for both laboratory and classroom instruction. The department maintains state-of-the-art Spatial Analysis Laboratory (SAL), Cartography Laboratory, the Laboratory for Applied Climate Research (LACR), and a Sediment Analysis Laboratory.

For more information, contact
Dr. Frank Ainsley
Department of Geography and Geology
University of North Carolina at Wilmington
601 South College Road
Wilmington, NC 28403-5944
Tel: (910) 962-4125
Fax: (910) 962-7077
ainsleyf@uncw.edu



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 thesis or non-thesis (general geography or planning concentrations) options
- Graduate Certificate in Planning

RESEARCH FACILITIES

The Department of Geography and Planning occupies part of a renovated science facility and contains classrooms, a reading room, map library, and two computer laboratories for work in computer cartography, GIS, and image processing. 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 map library and reading room hold maps, atlases, journals, and periodicals; the map library is a repository for material available on CD-ROM including TIGER files, DLGs, and other digital data.

GRADUATE PROGRAM

The Masters program in geography is designed to provide students with a 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. Thesis or non-thesis options are offered, with the non-thesis option requiring an internship in regional, urban, or environmental analysis and planning. The department has added a Graduate Certificate in Planning for individuals interested in a planning career.

For further information, please contact:

Department Chair: Dr. James Young (youngje@appstate.edu)
 Graduate Program Coordinator: Dr. Kathleen Schroeder (schroederk@appstate.edu)
 Program Inquiries: Kathy Brown (brownkv@appstate.edu)

Department of Geography and Planning
 Appalachian State University
 ASU Box 32066
 Boone NC 28608
 Phone (828) 262-3000
 Fax (828) 262 3067

Graduate Programs at The University of North Carolina at Charlotte



Ph.D. Program in Geography and Urban and Regional Analysis

The Ph.D. program focuses on two interconnected research themes: multi-scalar analysis and GIScience. Pairing technology and theory in the core curriculum, the doctoral program is designed to prepare graduates for research positions in the public and private sectors, as well as academic careers. Doctoral assistantships carry stipends of \$13,000 plus healthcare insurance, and a tuition waiver.

For further information contact Dr. Owen J. Furuseh, Director Geography Ph.D. Program at: ojfuruse@uncc.edu or via telephone at 704-687-4253.

Master of Arts in Geography Program Concentrations

Community Planning Track students are awarded the M.A. in Geography and complete a formally structured multi-disciplinary core curriculum with course work in Geography, Architecture, Economics and Public Administration. The Track has an excellent placement record.

Location Analysis Concentration students prepare for careers with retailers, real estate developers, consulting firms, commercial banks, and economic development agencies. Course work is offered by practicing professionals and focuses in: Retail Location, Market Area Analysis, Real Estate Development, Applied Population Analysis, Real Estate Development, and Industrial Location.

Urban-Regional Analysis Concentration trains students for public and private sector planning economic development and Geographic Information Science. Course work may be concentrated in one of the following areas: Economic and Regional Development, Site Feasibility Analysis, Urban Development, and Geographic Information Science.

Transportation Studies Concentration is affiliated with the University's Center for Transportation Policy Studies. Students pursue course work in Transportation Systems Analysis, Transportation Modeling, and Transportation Policy Analysis. Careers are available in public and private sector agencies and in consulting firms.

The M.A. program has a limited number of out-of-state tuition waivers and a significant number of graduate teaching or research assistantships. Typical stipends include awards of \$10,000 for the academic year. Current full-time students receive financial support via assistantships or via contract work.

For further information, visit our website at <http://www.geoeearth.uncc.edu/> or contact Dr. Tyrel G. Moore, Graduate Coordinator, Geography M.A. Program at tgmooore@uncc.edu, or via telephone at 704-687-5975.



THE UNIVERSITY OF NORTH CAROLINA

GREENSBORO

Department of Geography

Doctoral Degree in Geography

The doctoral program is centered on the research-oriented application of geographical theories to real-world problem-solving. The program provides advanced-level preparation in 3 areas: urban/regional economic development & planning, earth science/natural resource management, and geographic information science.

Master's Degree in Applied Geography

The Master's degree emphasizes the application of theoretical constructs in geography to solving problems, and also leads to the acquisition of research skills and expertise appropriate to geographic analysis, including spatial statistics, cartography, GIS, and remote sensing. Within the framework of the degree, one may also choose a concentration in urban planning and economic development.

Post-Baccalaureate Certificate in Geographic Information Science

The certificate provides professionals with the skills needed to utilize spatial analytic tools, geographic data visualization techniques, spatial programming, and geographic information and image processing software.

Post-Baccalaureate Certificate in Urban and Economic Development

This certificate requires courses emphasizing the knowledge and skills to prepare students to work in organizations focusing on urban planning and community economic development activities in the private sector, government and non-profit organizations.

Bachelor of Arts in Geography

For over half a century, our undergraduate program has prepared students for careers and advanced research in geography. Today the program is characterized by a strong integration of the human, physical, and technical components of the discipline. A geography major may choose a general degree or a degree with a concentration in either geographic information science, urban planning, or earth science/environmental studies.

For Undergraduate Information:

Contact: Dr. Michael Lewis
336-334-3912
melewis@uncg.edu

For Graduate Information:

Contact: Dr. Roy Stine
336-334-3915
geograd@uncg.edu



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.

Guidelines for Authors

The North Carolina Geographer is an annual, peer-reviewed journal published by the North Carolina Geographical Society and serves as a medium for the dissemination of research concerning phenomena of regional interest. Contributions are welcome and should conform to the Guidelines for Authors presented below.

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 electronic copy and one original and two hard copies of the manuscripts. Only original, unpublished material will be accepted.
- All manuscripts should be on 8 1/2 " 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 author's last name. Please follow the *Annals of the Association of American Geographers* reference format.
- Figures and tables should be submitted on separate pages at the end of the manuscript and electronic versions of figures should be TIFF format. Provide a list of figure and table captions on a page separate from the main text of the manuscript.
- High quality, black and white photographs may be included.

Send manuscripts to:

The North Carolina Geographer

Department of Geography and Geology

University of North Carolina at Wilmington

601 S. College Rd.

Wilmington, North Carolina 28405

Telephone: (910)962-3778

Fax: (910)962-7077

E-mail: gambled@uncw.edu

The North Carolina Geographer

Volume 14, 2006

Research Articles

- Streamflow Duration and Recreational Flows on Three Southeastern Streams.....1
Michael W. Mayfield, Appalachian State University
- Asian and Hispanic Settlement Patterns in the Counties of North Carolina, 2000.....13
Evelyn D. Ravuri, Saginaw Valley State University
- The Effects of Local Weather Patterns on Nitrate and Sulfate Rainwater
Concentrations in Wilmington, North Carolina.....29
*Sarah Beth Jenkins, Douglas W. Gamble, Michael M. Benedetti, and Joan Willey, Univeristy of
North Carolina Wilmington*

Carolina Landscapes

Book Review

- North Carolina Weather and Climate. Peter J. Robinson, The University of North
Carolina Press, Chapel Hill, North Carolina, 2005. , 256 pp.....39
Sol Wuensch, East Carolina University
- Request for Submissions & Guide for Authors.....46

