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Demographic shifts around drinking water supply reservoirs in North Carolina, USA

Michael D. Youth[a], George R. Hess[a], M. Nils Peterson[a], Melissa R. McHale[a] & Kevin M. Bigsby[a]

[a] Department of Forestry & Environmental Resources, North Carolina State University, Raleigh, NC 27695-8008, USA

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Michael D. Youth[†], George R. Hess[*], M. Nils Peterson, Melissa R. McHale and Kevin M. Bigsby

Department of Forestry & Environmental Resources, North Carolina State University, Raleigh, NC 27695-8008, USA

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Infrastructure intended to serve the public good frequently has implications for environmental justice and social sustainability. Drinking water supplies for sub/urban areas in North Carolina, USA, have regularly been secured by constructing dams to impound reservoirs. We used high-resolution, publicly available US Census data to explore whether 66 such reservoirs in North Carolina have induced demographic shifts in the communities that find themselves adjacent to the newly created lakeshores. Our principal findings include: (1) The ratio of white people to non-white people was significantly higher in communities within 0.5 miles of reservoir shorelines than in more distant communities; (2) even as North Carolina overall became less white from 1990 to 2010, the ratio of white people to non-white people within the 0.5 miles of the shoreline increased relative to the overall ratio in the State; and (3) similar, but less distinct, shifts in *per capita* income occurred during the period. Our results are consistent with the proposition that reservoirs have induced demographic shifts in communities adjacent to newly created lakeshores similar to the shifts associated with environmental gentrification and amenity migration, and may now be associated with perpetuating those shifts. These findings raise concerns about environmental justice and social sustainability that should be considered when planning and building infrastructure that creates environmental amenities. Where reservoirs are being planned, social costs, including the costs of demographic shifts associated with environmental gentrification or amenity migration, and disproportionate regulatory burdens, should be mitigated through innovative policy if possible.

Keywords: amenity migration; dam; environmental justice; environmental gentrification; gentrification; North Carolina; reservoir; social sustainability

1. Introduction

The growth of many sub/urban populations is outstripping the capacity of drinking water reservoirs (Moreau 1992a), raising reliability concerns as climate change is predicted to cause boom-and-bust hydrological cycles that will challenge water supply resources in many regions of the world (Pickett *et al*. 2001, Burgess 2009, Cheng and Zhao 2009,

*Corresponding author. Email: george_hess@ncsu.edu
[†]Current address: NC Sustainable Energy Association, Raleigh, NC, USA.

EPA 2009, pp. 66532–66533). The twin pressures of population growth and climate change will likely prompt decision-makers to plan for more reservoirs, despite the existence of a substantial anti-dam movement (e.g. McCully 2001, Routhe *et al*. 2005, Moreau 2008, Shah and Kumar 2008, Glennon 2009). North Carolina's legislature serves as an example: N.C. Session Law 2011–374 (2011) directed the State's Clean Water Management Trust Fund to be used to, among other things, preserve lands for water supply reservoirs.

While dams built to impound drinking water supply reservoirs benefit the communities served by the supplies, they impose social costs as well. The displacement of 40–80 million people worldwide (WDC 2000) is the most thoroughly documented social cost associated with reservoir impoundment. However, displacement is not the only social issue associated with dams that merits assessment, and there are calls for greater attention to the effects of land-use change and amenity-creating infrastructure on social sustainability (e.g. Pearsall *et al*. 2012, Ahman 2013, Curran and Hamilton 2012). A reservoir's social benefits, including providing a reliable drinking water supply, flood protection for downstream communities, and the creation of new environmental amenities (i.e. lakes) should be understood and balanced against a reservoir's social costs and tempered by a concern for justice. These costs may include displacement and social disruption of poor or minority communities that find themselves adjacent to the new lake, and imposition of disproportionate regulatory burdens (e.g. restrictions on land use borne by upstream communities to maintain the drinkability of water supplies they do not use).

We speculated that reservoirs might lead to demographic shifts in communities suddenly adjacent to lakeshore property similar to shifts seen in cases of environmental gentrification and amenity migration (e.g. Partridge 2010, Gamper-Rabindran and Timmins 2011, Finewood 2012, Pearsall *et al.* 2012), changing them from communities of lower to higher white population (%) or *per capita* income. Environmental gentrification, typically discussed in urban settings, and amenity migration more broadly, both involve such demographic shifts after environmental improvements, including golf courses (Wells *et al.* 2008), parks (Rowan and Fridgen 2003, Curran and Hamilton 2012), redeveloped brownfields (Rowan and Fridgen 2003, Curran and Hamilton 2012), and street trees (Landry and Chakraborty 2009).

Reservoirs tend to be built in the USA and globally where low-income people and people of colour live (WDC 2000, Egre and Senecal 2003). Colchester (2000), for example, noted that poor black sharecroppers bore the brunt of the social impacts of the Tennessee Valley Authority's dam-building programme undertaken in the Southeastern United States from 1933 to 1946. Beyond tending to be sited in low-income and minority communities, anecdotal evidence in North Carolina suggests that reservoirs induce demographic changes, proving through time to be an amenity attracting higher income or white residents to the lakeside communities and making it difficult for lower income people or minorities to remain.

Despite the anecdotal evidence, we found that almost no research has focused on the demographic changes that occur in these newly created lakeside communities (Scudder 1997). In the only study we found of such communities, Burby *et al.* (1973) surveyed more than 400 people to explore how US Congressional authorisation of two North Carolina dams – eventually impounding Jordan and Falls Lakes near Raleigh, NC, USA – affected the communities within three miles of the proposed reservoir shorelines. Covering the period of time from five and six years before Congressional authorisation to five and six years after authorisation, they found that blacks comprised 9.3% of the Jordan Lake and 6.4% of the Falls Lake pre-authorisation landowner samples, but only one black land purchaser fell into the post-authorisation samples (pp. 96–97). They also found that pre-authorisation landowners were more likely to have much lower annual incomes than post-authorisation landowners (pp. 98–99). Given the study's limited post-authorisation temporal scope and the fact that neither lake was actually impounded within the study's time-frame, the study emphasises the need for a greater understanding of reservoirs' social impacts through time.

1.1. Objectives

Based on Burby *et al.*'s (1973) research, we developed four hypotheses – two pertaining to race and two pertaining to income – to help us explore our core inquiry: Are there indications that drinking water supply reservoirs built for North Carolina's sub/urban areas induce demographic changes in the communities that find themselves adjacent to the resulting lakeshore property? Our first two hypotheses are spatial in nature and were designed to test whether any race or income patterns of concern exist. Our second two hypotheses are temporal in nature and were designed to explore the evolution of race and income patterns.

(1) White population percentage is significantly higher in the areas within 0.5 mile of North Carolina's sub/urban drinking water supply reservoirs than in the areas 0.5–1 mile, 1–3 miles, and 3–5 miles away from the reservoirs.
(2) *Per capita* income is significantly higher in the areas within 0.5 mile of reservoirs than in the areas 0.5–1 mile, 1–3 miles, and 3–5 miles away.
(3) White population percentage is significantly higher in the areas within 0.5 mile of reservoirs in 2010 than in 2000 and in 2000 than in 1990.
(4) *Per capita* income is significantly higher in the areas within 0.5 mile of reservoirs in 2000 than in 1990. We did not carry this hypothesis to 2010 because the Great Recession fundamentally altered income patterns in the latter half of this decade.

A greater understanding of the effect of sub/urban drinking water supply reservoirs on lakeside communities will enable advocates and decision-makers to more fully analyse the benefits and costs of such reservoirs and evaluate their place in a socially sustainable society (Tilt *et al*. 2009). Such an understanding may also drive the design and implementation of innovative mitigation policies.

2. Study Area

2.1. Overview of race in North Carolina

North Carolina's racial demography is overwhelmingly a story of black and white. While the non-white/non-black populations in North Carolina grew from 1.4% to 10% of the total population between 1990 and 2010, the white and black populations together comprised close to 100% of the total population for more than 200 years before 1990 (Parker 2010, US Census Bureau 2011). The enslavement of blacks was legalised in North Carolina in 1715 (Larkins 1944), and slavery quickly became concentrated in the coastal plains and piedmont regions where the plantation system prevailed (Figure 1) (Johnson 1937, Larkins 1944).

In 1860, free blacks comprised 3.3% of the State's total population and 8.4% of the State's total black population. The slave population density was the greatest in the State's north-eastern counties, along the Virginia border (Larkins 1944). Sixteen counties contained more slaves than whites and all but three were situated in the coastal plains region (Johnson 1937). The mountain counties were overwhelmingly white with relatively few slaves (Larkins 1944). The piedmont region served as a demographic transitional area between the two extremes. The free black population distribution generally followed that of the slave population, with the largest numbers of free blacks residing in the counties having the largest slave populations (Johnson 1937). In 1940, 75 years after the abolishment of slavery, most of North Carolina's black population remained concentrated in approximately 47 of North Carolina's 100 counties, located in the piedmont and coastal plains regions.

On a more granular level, as of 1860, only 10.5% of the free black population and a very small percentage of enslaved blacks lived in sub/urban areas. Though the general distribution of blacks throughout the State did not change significantly between 1860 and 1940, blacks did begin moving into sub/urban areas. By 1940, 30.7% of the individuals classified as urban dwellers in North Carolina were black (Larkins 1944). Since 1940, North Carolina's black population has continued its transformation into an overwhelmingly sub/urban population. As of 2010, 36% of the State's black population lived in just six cities – Charlotte, Durham, Fayetteville, Greensboro, Raleigh, and Winston-Salem – and 68% (1,392,351 out of 2,048,628 individuals) lived in the State's 222 cities and towns with populations greater than 2500 (LINC 2011).

2.2. *Overview of income in North Carolina*

Per capita income in North Carolina appears correlated with urbanisation. From 1969 to 1999, counties situated in the piedmont-based crescent of urbanisation – a swath extending north from Charlotte to Winston-Salem and east to Raleigh – have consistently had *per capita* incomes in the State's top quartile. During this same period, the less urbanised mountain and interior coastal plains counties have tended to have *per capita* incomes in the lowest two quartiles. A racial disparity persists to this day in *per capita* income in the State. In 2010, the overall *per capita* income in the State was $24,014; for blacks, it was $16,478 (2010 dollars) (Social Explorer 2014).

2.3. *Overview of sub/urban drinking water supplies in North Carolina*

Around 1990, North Carolina's population became more urban than rural, and has since become increasingly more urban (Parker 2010, US Census Bureau 2011). The State's urban population is concentrated in the piedmont region (Howells 1989). North Carolina

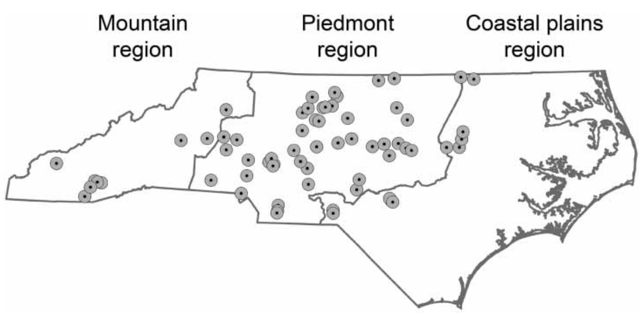

Figure 1. The three regions of North Carolina and the 66 drinking water supply reservoirs. Nine of the 66 drinking water reservoirs we examined are located in the mountain region of the State; 46 are located in the piedmont region; and 11 are located in the coastal plains region.

has only 15 major natural lakes, all situated in the State's coastal plains region (Drake and Bromley 1997). Consequently, the sub/urban population relies primarily on reservoirs for its drinking water supply (Burgess 2009). As of 2008, North Carolina contained more than 5000 dams; 162 of these dams impound at least 1000 acre-feet of water (Moreau 2008). Historically in North Carolina, the land needed for impoundment of a reservoir was often obtained under a power of eminent domain and paid for using public dollars (N.C. Court of Appeals 1981). Consequently, sub/urban drinking water supply reservoirs were typically built in less densely populated areas where land values were lower.

3. Methods

We acquired US Census data for North Carolina from the decennial census, including race data at the block level (the highest resolution publicly available), for the years 1990, 2000, and 2010; and *per capita* income data at the block group level (the highest resolution publicly available) for the years 1990 and 2000. We acquired 2010 *per capita* income data from the 2008–2012 American Community Survey, because of a transition in US Census data collection methods for income data. All *per capita* income data were converted to year 2000 dollars. We were limited to the three most recent decadal Census years because high-resolution block level Census data are not publicly available for North Carolina prior to 1990. We acquired the tabular, numeric data, and geographic information system files containing the Census geographic units from the Minnesota Population Center (2011), the Missouri Census Data Center (2011), Log Into North Carolina (2011), and the Social Explorer (2014).

For each Census year, we used a geographic information system (ArcGIS) to create a spatial data set based on US Census blocks. For each block, we calculated an overall population density and a white population density. We assigned each block the *per capita* income of the block group within which it was nested. We called the resulting shapefiles "Census baselayers".

We used a 2006 report submitted to the State's Environmental Management Commission to identify the 66 North Carolina sub/urban drinking water reservoirs situated in more developed Class III, IV or V watersheds (Figure 1) (EMC 2006, North Carolina Administrative Code Chapter 15A, Section 2B.0301 2011).

Having identified a near-census sample of these reservoirs, we secured existing geographic information system reservoir boundary files – relying primarily on data released by North Carolina's Department of Environment and Natural Resources – or we created new boundary files using Google Earth. We used ArcGIS v.9.3.1 to create four buffers around each reservoir. These buffers, based on distances commonly used in environmental justice research and the 0.5 and 5 mile distances used in North Carolina water quality regulations, extended (1) from the shoreline to 0.5 mile out; (2) 0.5-1 mile out; (3) 1-3 miles out; and (4) 3-5 miles out (Mohai and Saha 2006, North Carolina Administrative Code Chapter 15A Sections 2B.0202 (20) & (53) 2011). It is worth noting that the referenced North Carolina regulations became effective in 1992, at approximately the same time as the beginning of our study period (Moreau 1992b, Dehring and Depken 2010). We populated each buffer with information from our Census baselayers and used area weighting to estimate the overall population, white population, and *per capita* income of each buffer.

We used an Excel spreadsheet to capture (1) data for each reservoir that might explain any differences we discovered, including year built, reservoir surface area, geographic region, and whether the reservoir has a regulatory critical area or accommodates primary recreation such as organised swimming; and (2) the results of our ArcGIS analysis for each buffer for each Census year. We used SAS v.9.2 with Enterprise Guide 4.2 to run analyses of variance (ANOVAs) of the effect of buffer distance from a reservoir on race and, separately, income, and in all cases took into account the variation among the 66 reservoirs. Race and income were treated separately because correlations between white population (%) and *per capita* income ranged from a high *r*-value of 0.37 in the 0–0.5 mile buffer in 2000 to a low of 0.14 in the 1–3 mile buffer in 1990.

4. Results

4.1. Testing the spatial race hypothesis

Though the demographics around the 66 reservoirs we examined were highly variable, the overall white proportion of the populations living within 0.5 mile of the reservoirs was significantly higher than the white proportions of those living in the areas 1–5 miles from the reservoirs ($\alpha = 0.05$). This was true for each of the years examined (Table 1 and Figure 2).

The disparity between the white population (%) in the 0–0.5 mile buffer and the other buffers displayed regional differences (Table 2). Without exception, the regional means for each of the buffers grew higher as one moved from coastal plains to piedmont to mountain region. In the coastal plains, we found no significant differences ($\alpha = 0.05$) in mean white population (%) between any buffers regardless of year. In the piedmont, where most of North Carolina's drinking water supply reservoirs are situated, we saw significantly higher mean white populations (%) in the 0–0.5 mile buffer compared to each of the

Table 1. Results of ANOVAs for mean white population (%) by distance from lakeshore (1990–2010).

	Distance from Lakeshore/Census year				
	0–0.5 mi	0.5–1 mi	1–3 mi	3–5 mi	County
	86.6% (1990) 84.8% (2000) 81.2% (2010)	82.4% (1990) 80.2% (2000) 76.5% (2010)	79.4% (1990) 76.0% (2000) 71.6% (2010)	78.3% (1990) 74.4% (2000) 70.3% (2010)	77.2% (1990) 73.4% (2000) 69.6% (2010)
0–0.5 mi					
86.6% (1990)		0.0939	0.0003*	<0.0001*	<0.0001*
84.8% (2000)		0.0272*	<0.0001*	<0.0001*	<0.0001*
81.2% (2010)		0.0288*	<0.0001*	<0.0001*	<0.0001*
0.5–1 mi					
82.4% (1990)			0.3917	0.1113	0.0195*
80.2% (2000)			0.0624	0.0029*	0.0002*
76.5% (2010)			0.0193*	0.0014*	0.0002*
1–3 mi					
79.4% (1990)				0.9657	0.6896
76.0% (2000)				0.8623	0.4762
71.6% (2010)				0.9386	0.7336
3–5 mi					
78.3% (1990)					0.9668
74.4% (2000)					0.9663
70.3% (2010)					0.9908

Notes: An ANOVA comparing mean white population (%) for each buffer for a given Census year (left column) to the other three buffers and to the immediate surrounding counties for that year (top row) yielded a number of significant differences ($\alpha = 0.05$), denoted in the table by asterisks (*). The 0–0.5 mile buffer was consistently significantly different from the 1–5 mile buffers and the surrounding counties throughout the 20-year period. The 0.5–1 mile buffer became increasing less like the 1–5 mile buffers over the course of the 20-year period.

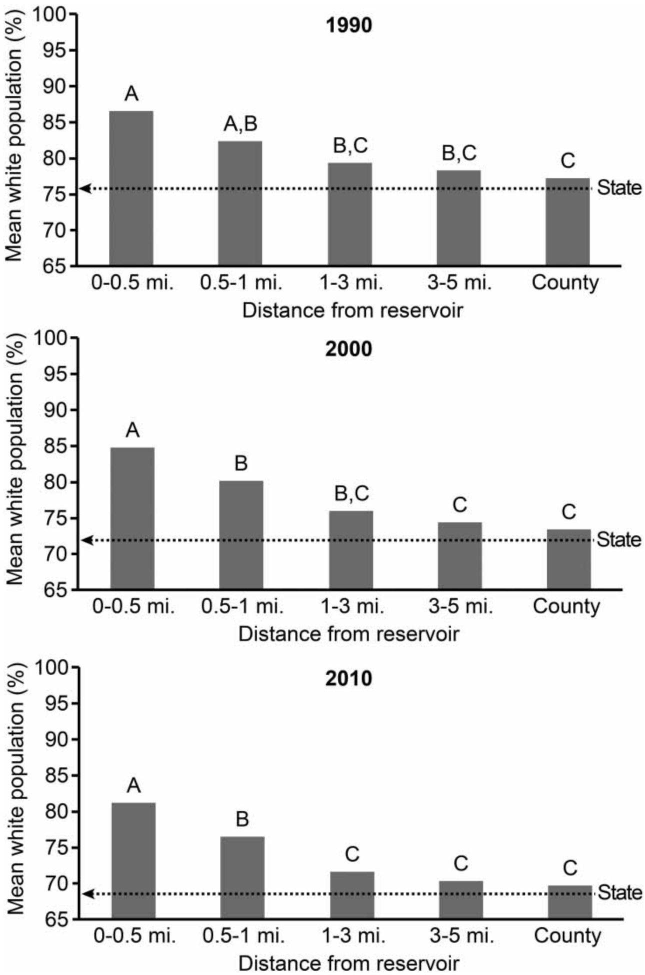

Figure 2. Results of ANOVAs for mean white population (%) by distance from lakeshore (1990–2010). Bars that are not topped with the same letter are significantly different ($\alpha = 0.05$). The dashed line represents the average white population (%) in North Carolina. For each of the three years – 1990, 2000, and 2010 – the proportion of whites living within 0.5 mile of the 66 examined reservoirs was significantly higher than the proportion living in areas 1–5 miles away and, in 2000 and 2010, was significantly higher than the proportion living 0.5–1 mile away as well.

other buffers for each of the three Census years examined; we also saw a significantly higher mean white population (%) in the 0.5–1 mile buffer compared to the 1–5 mile buffers for 2000 and 2010. Finally, in the mountains, there were significantly higher mean white populations (%) in the four 0–5 mile buffers compared to the surrounding counties in 1990 and 2000, and between the 0–1 mile buffers and the surrounding counties in 2010.

Twenty-six reservoirs in our sample accommodate primary recreational use such as organised swimming (EMC 2006). For these 26 lakes, there was a significantly higher mean white population ($p < 0.05$) in the 0–0.5 mile buffer (ranging from 90.4% to 91.9%) compared to the 1–5 mile buffers (ranging from 75.8% to 85.2%, $p < 0.05$) in each of the three years examined. The same significant difference ($p < 0.05$) existed

Table 2. Mean white population (%) by distance from lakeshore by region (1990–2010).

	Distance from Lakeshore				
Census year	0–0.5 mi (%)	0.5–1 mi (%)	1–3 mi (%)	3–5 mi (%)	County (%)
Coastal plain reservoirs ($n = 11$)					
1990	71.5	70.6	67.4	62.8	63.2
2000	65.2	63.9	60.7	56.5	57.7
2010	59.9	58.0	55.6	52.2	53.9
Piedmont reservoirs ($n = 46$)					
1990	88.4	82.4	78.8	78.5	78.1
2000	87.3	81.0	76.0	74.8	74.4
2000	83.4	77.5	71.6	70.7	70.3
Mountain reservoirs ($n = 9$)					
1990	96.1	97.0	97.2	96.4	89.9
2000	96.1	95.7	94.4	94.2	87.3
2010	95.8	93.6	90.7	90.4	85.2

Note: Generally speaking, throughout the 20-year period examined, the mean white population (%) in the four buffers and in the immediate surrounding counties is the highest in the mountain region followed by the piedmont region and then the coastal plains region.

between the 0–0.5 mile buffer (ranging from 75.2% to 83.2%) mean and the 1–5 mile buffer means (ranging from 66.7% to 75.7%) for the 40 reservoirs that do not accommodate primary recreational uses, though the means for these 40 lakes were lower across the board.

Lastly, we examined the 49 reservoirs in our sample that had regulatory critical areas as of 2006 (EMC 2006). The critical area for a reservoir can be roughly defined as within 0.5 mile of the drinking water supply reservoir (Dehring and Depken 2010, North Carolina Administrative Code Chapter 15A Section 2B.0202 (20) 2011). New residential development in a critical area is subject to a two-acre minimum lot size (Dehring and Depken 2010). Parsing the reservoirs in this way revealed the familiar spatial pattern of higher white population (%) in the buffers closer to the reservoirs and did not alter the consistent, significant difference between the 0–0.5 mile lakeside buffer area and the 1–5 mile buffer areas (Table 1).

4.2. *Testing the spatial income hypothesis*

There were no significant differences in *per capita* income between the lakeside 0–0.5 mile area and other areas in 1990 (Figure 3, Table 3). In 2000, the mean *per capita* income of those living within 0.5 mile of the reservoirs was significantly higher than the mean *per capita* income of those living in the areas 1–5 miles from the reservoirs ($\alpha = 0.05$). In 2010, the mean *per capita* income within 0.5 miles of the reservoirs was significantly higher than the *per capita* income within 3–5 miles.

4.3. *Testing the temporal race hypothesis*

The white proportion living within 0.5 mile of the reservoirs decreased through time, but this was true in all buffers regardless of distance from the reservoirs and is consistent with the decreasing proportion of whites in the State between 1990 and 2010. However, when we standardised the white proportions relative to the State mean (Equation (1)), it became evident that the white population (%) in the 0–0.5 mile lakeside area was not decreasing as quickly as it was in the buffers more distant from the reservoirs (Figure 4).

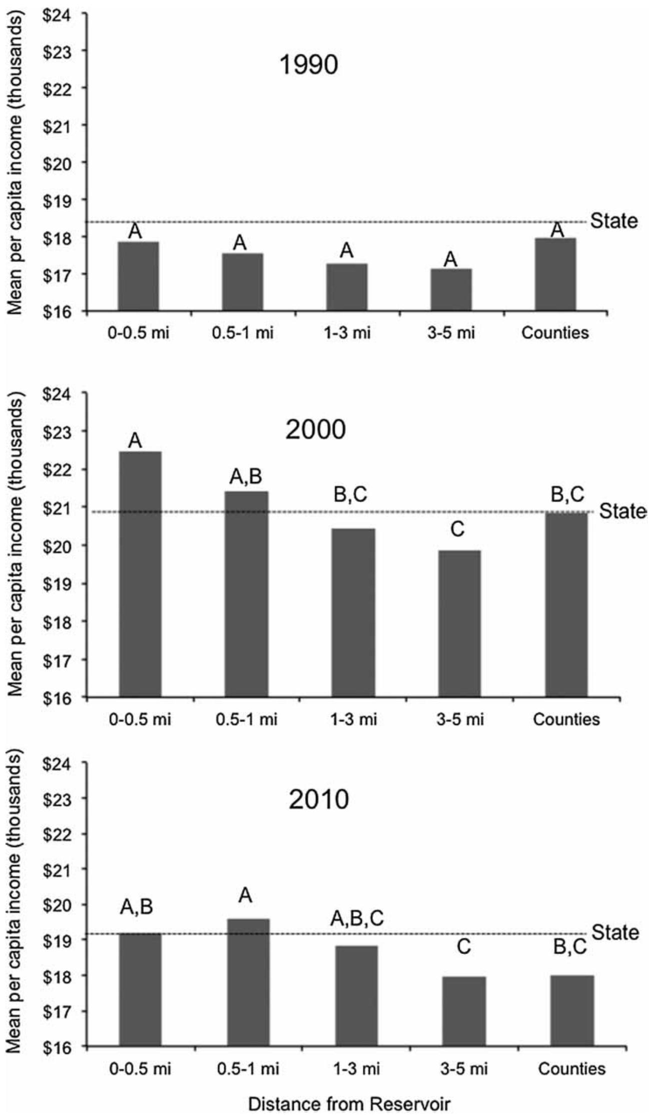

Figure 3. Results of ANOVAs for mean *per capita* income (adjusted to year 2000 dollars) by distance from lakeshore (1990–2010). Bars that are not topped with the same letter are significantly different ($\alpha = 0.05$). The dashed line represents the average *per capita* income in North Carolina. In 1990, there were no significant differences between the lakeside and more distance areas. In 2000, the lakeside area up to 1 mile away had a significantly higher *per capita* income than the areas 1–5 miles away. In 2010, the area up to 1 mile away had significantly higher *per capita* income than areas 3–5 miles away.

This slower decline in mean white population (%) was significant in the 0–0.5 mile buffer between 1990 and 2000:

$$\frac{\text{White population (\%) for buffer} - \text{Mean white population (\%) for the State}}{\text{Mean white population (\%) for the State}}. \quad (1)$$

Table 3. Results of ANOVAs for mean *per capita* income by distance from lakeshore (1990–2010).

	Distance from Lakeshore/Census year				
	0–0.5 mi	0.5–1 mi	1–3 mi	3–5 mi	County
	\$17,873 (1990) \$22,467 (2000) \$19,185 (2010)	\$17,558 (1990) \$21,401 (2000) \$19,606 (2010)	\$17,292 (1990) \$20,428 (2000) \$18,849 (2010)	\$17,136 (1990) \$19,870 (2000) \$17,958 (2010)	\$17,951 (1990) \$20,833 (2000) \$17,995 (2010)
0–0.5 mi					
\$17,873 (1990)		0.9381	0.6129	0.3720	0.9997
\$22,467 (2000)		0.2047	0.0005*	<0.0001*	0.0101*
\$19,185 (2010)		0.8737	0.9409	0.0444*	0.0557
0.5–1 mi					
\$17,558 (1990)			0.9664	0.8397	0.8715
\$21,401 (2000)			0.2902	0.0193*	0.7841
\$19,606 (2010)			0.4231	0.0020*	0.0028*
1–3 mi					
\$17,292 (1990)				0.9953	0.4901
\$20,428 (2000)				0.7945	0.9258
\$18,849 (2010)				0.2557	0.2970
3–5 mi					
\$17,136 (1990)					0.2702
\$19,870 (2000)					0.3001
\$17,958 (2010)					1.0000

Note: An ANOVA revealed significant differences in 2000 ($\alpha = 0.05$), denoted in the table by asterisks (*).

4.4. Testing the temporal income hypothesis

We noted a significant increase in *per capita* income between 1990 and 2000 within each of the buffers (Figure 3). Once we standardised relative to the State mean (Equation (2)), it became evident that *per capita* income grew between 1990 and 2000 at a faster rate in the 0–0.5 mile buffer than in any other buffer:

$$\frac{\text{Per capita income for buffer} - \text{Per capita income for the State}}{\text{Per capita income for the State}}. \quad (2)$$

Income decreased at all distances from the lake between 2000 and 2010, most likely a result of the Great Recession towards the end of that decade, which fundamentally altered income patterns.

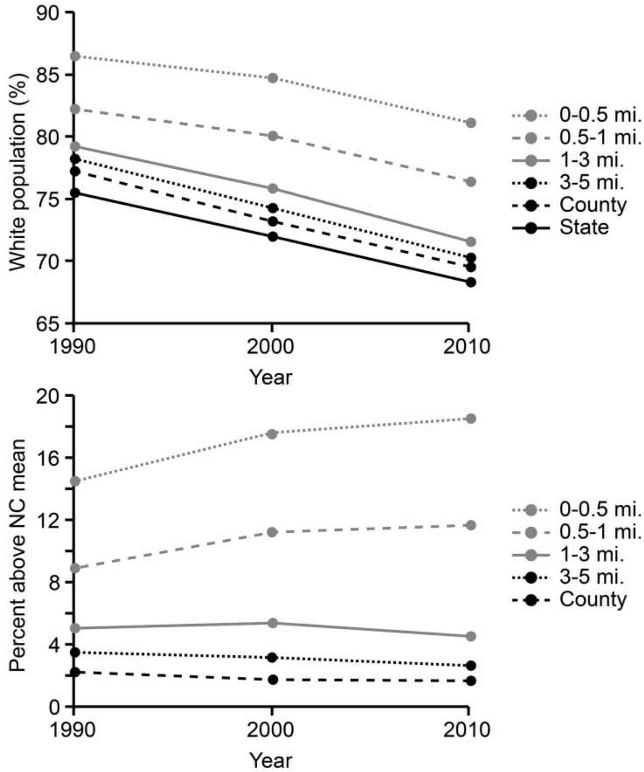

Figure 4. Mean white population (%) by distance from lakeshore through time (1990–2010). The non-standardised graph (upper) illustrates how the mean white population (%) decreased between 1990 and 2010 in each of the buffers we examined and in the State as a whole. We standardised our results to show the degree to which mean white population (%) in each buffer exceeded the white population (%) for the State (see Methods for details). The standardised graph (lower) illustrates how, despite the overall trend, the mean white population (%) in the communities within 1 mile of a reservoir tends to be decreasing at a slower rate and hence the gap between these communities and the overall State mean has actually increased over time. The only significant increase took place in the 0–0.5 mile buffer between 1990 and 2000.

5. Discussion

5.1. Contextualising our results

Mohai *et al*. (2009) traced the history of research into the tendency of disamenities, or locally unwanted land uses, such as waste sites, to be situated in communities that are disproportionately minority or low-income. Their research reflected the tendency of locally unwanted land uses to perpetuate or reinforce the pre-existing demographics in minority or low-income communities in which they are sited. Others have explored presumptive amenities or locally desirable land uses that tend to be situated in communities that are disproportionately white or higher income (Wells *et al*. 2008, Landry and Chakraborty 2009). Amenities likewise appear to perpetuate or strengthen the demographics in the communities in which they are located, but may also lead to environmental gentrification and amenity migration that push out minorities and people of lesser economic means (e.g. Checker 2011, Curran and Hamilton 2012). Because North Carolina's sub/urban drinking water reservoirs have characteristics of both a disamenity (e.g. displacement) and an amenity (e.g. lakeside housing, recreation), we chose to explore whether these reservoirs fell clearly within the disamenity or amenity class of infrastructure or, as we hypothesised, into a third class of infrastructure that precipitates a demographic shift through time in adjacent communities from lower to higher white population (%) or *per capita* income (e.g. Gamper-Rabindran and Timmins 2011).

5.2. Interpreting our results

The demographic changes around the water supply reservoirs we examined raise environmental justice and social sustainability concerns. Our race-based spatial results revealed a consistent tendency towards numerical inequality or disproportionality: The mean white population percentage is significantly higher in the areas within 0.5 mile of the reservoirs than in the areas 1–5 miles away from them (Table 1, Figure 2). Our results are consistent with the proposition that drinking water supply reservoirs have induced demographic shifts in communities near newly created lakeshores similar to those associated with environmental gentrification and amenity migration, and may now be associated with perpetuating those effects. Most black North Carolinians live in the piedmont and coastal plains regions of the State, reflecting the pre-US Civil War prevalence of slaves in these regions (Figure 1). This legacy effect does not, however, account for the underrepresentation of non-whites in the communities living within 0.5 mile of reservoirs. Our race-based temporal results are more nuanced because communities within 0.5 mile of the lakes became whiter through time relative to the State as a whole (Figure 4). This trend could be viewed as indicative of ongoing demographic shifts. These two trends together may reflect a transition into community gating, the process in which amenities are sited in communities with higher white populations (%) or *per capita* income and perpetuate or reinforce those characteristics of the community (e.g. Landry and Chakraborty 2009).

Although the increase in standardised white population near reservoirs through time was relatively small, it is possible that a marked increase in mean white population percentage expressed itself quickly and prominently and our research simply did not go back far enough in time to capture this expression. Several points suggest this is likely. Reservoirs generally tend to be built in areas occupied by minorities (e.g. WDC 2000, Egre and Senecal 2003). Our race-based spatial results consistently indicated a significantly higher white population percentage in the 0–0.5 mile lakeside communities than in the communities a mile or more from the reservoirs. As of 1990, the beginning of the period we examined, the mean age of the reservoirs we reviewed was 43 years. Burby *et al.* (1973) noted an apparent demographic shift within just a few years of dam authorisation, even before construction of dams was completed. These points suggest the distinct possibility that whites moved into North Carolina's newly created lakeside communities in disproportionate numbers shortly after the dams were authorised and constructed, and our study captured a relatively small proportion of that shift.

If one assumes that demographic shifts to higher *per capita* income and proportion of white residents in the 0–0.5 mile lakeside buffer areas began prior to 1990, our results can be explained as representative of areas that are now being "gated" against the racial integration taking place more generally in the State. Land-use laws designed to ensure clean drinking water might be having the unintended consequence, by driving up property values, of contributing to demographic shifts similar to those seen in environmental gentrification or amenity migration. North Carolina's reliance on dammed reservoirs has manifested itself in fairly recent, far-ranging regulatory action designed to ensure the quality of these impounded waters (Moreau 1992b, Dehring and Depken 2010). The creation of "critical" areas around 49 of the 66 reservoirs that proscribe how large (and thus how expensive) a residential parcel must be might be serving to further gate these communities, keeping out people of lesser economic means.

The most optimistic explanation of our race-based spatial and temporal results is that they reflect cultural preference. Researchers should be able to test this explanation through future survey work. However, such survey work may itself introduce new questions and complexities. For example, during our research, we learned from Larkins (1944) that, as of 1943, there were only five North Carolina communities that provided recreational swimming pools and parks for "Negroes" – High Point, Raleigh, Durham, Greensboro, and Winston-Salem (p. 47). Burby (1967) hypothesised that developers did not wish to build lakeside communities "… in a low income area or adjacent to Negro residences" (p. 49). Though the evidence collected by Burby was insufficient to support his hypothesis, the hypothesis itself says something about white cultural expectations for racial segregation at the time.

The literature on this topic points to several other cases in which social and cultural preferences for certain landscapes or recreational experiences may actually be a legacy of past racial segregation (Starkey 2005, Van Velsor and Nilon 2006, Chen 2009, Frey 2010, Peterson *et al*. 2012). Our findings and studies like these provide a foundation for asking questions such as: Even if today's blacks and other non-whites do not, for example, perceive access to recreational swimming to be a significant amenity and consequently prefer not to live in lakeside communities, is this preference a derivative of their forebears having been excluded from opportunities to develop the opposite preference? In other words, is any cultural preference the result of thoughtful deliberation or mere acquiescence to past discrimination, and what does the potential for acquiescence mean? If, however, our results reflect isolation of blacks from a key environmental amenity against their will, we may need to identify ways to address the problem when planning future reservoirs.

Policy mechanisms for responding to such a problem can reduce the costs (including opportunity costs) of staying in lakeshore environments and provide incentives for new housing that accommodates lower income residents. Reducing the costs of staying often involves tax policy, and may by typified by California's Proposition 13 which prohibited reassessment of a new base year home value for residents who stayed in the same home (O'Sullivan 1995). Incentive policies to accommodate lower income residents are more diverse, but are well represented by the "anti-snob" zoning pioneered in Massachusetts and later adopted in several other states (Peterson *et al*. 2013). These policy models provide developers density bonuses to include a minimum amount of low-income housing, and allow developers to ignore other local ordinances if municipalities contain inadequate amounts of affordable housing (e.g. $<10\%$ in the original Massachusetts legislation).

6. Conclusion

Racially, our results evidence a numerical inequality or disproportionality around North Carolina drinking water supply reservoirs similar to those associated with environmental gentrification, amenity migration, or community gating and should therefore be of concern to decision-makers considering future drinking water supply reservoirs. Our results draw attention to a potential societal cost associated with such reservoirs. It is for advocates and decision-makers to weigh the complex costs and benefits of a particular dammed reservoir and determine on a case-by-case basis whether an injustice is occurring and, if so, whether any mitigation measures should be implemented. The balancing should, at a minimum, account for a reservoir's social benefits – including for poor and minority populations – such as providing a reliable drinking water supply and providing flood protection for downstream communities. It should also account for a reservoir's social costs including displacement of the poor and minorities, the likelihood of displacement of poorer or minority communities that find themselves adjacent to lakeshores, and any disproportionate regulatory burdens.

Our work contributes meaningfully to any discussion of the following two questions: (1) Have existing reservoirs produced an injustice in North Carolina lakeside communities and, if so, are corrective measures merited? (2) Can future reservoirs be built in the State in such a way that they create reliable and fair supplies of drinking water? The infrastructure we examined – North Carolina sub/urban drinking water supply reservoirs – may by its very unmitigated existence turn adjacent poor or minority communities into higher income or whiter communities. Additionally, the regulatory infrastructure that society chooses to maintain the quality of the impounded drinking water may effectively be erecting a barrier or "gate" to proportionate integration of the poor and minorities into the lakeside neighbourhoods. Absent further research, we cannot rule out the possibility that reservoirs as a class are working an injustice in North Carolina lakeside communities. Future studies should explore potential mechanisms behind the patterns we have identified, including preferences for residences proximate to water, mountains, urban, and rural environments (e.g. Deller *et al*. 2001, Argent *et al*. 2014).

More generally, our research contributes to any discussion about the interaction between infrastructure and demographics. Green infrastructure, economic redevelopment, and environmental remediation can create environmental amenities and perpetuate modes of discourse about development, growth, and sustainability that marginalise and push out minorities and less wealthy communities by dramatically increasing property values in an area (e.g. Finewood 2012, Curran and Hamilton 2012). An increased focus on the social aspects of sustainability is warranted during planning and development processes, including meaningful involvement of diverse publics in decision-making. If we, as a society, believe that "the *fairest* good for the greatest number" is integral to social sustainability, we have an obligation to pursue clarification of the social impacts of drinking water supply reservoirs and other infrastructure.

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