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Demography of disaster: Population estimates after hurricane Andrew

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Abstract. Hurricane Andrew blasted through the southern tip of Florida in August 1992, damaging or destroying tens of thousands of homes and forcing hundreds of thousands of persons to move at least temporarily to different places of residence. The hurricane not only disrupted the lives of many Floridians, but destroyed the statistical basis for producing local population estimates in South Florida as well. These estimates are used for many types of decision-making, from the distribution of state revenue-sharing dollars to choosing sites for fast-food restaurants. This article describes the estimation problems created by the hurricane and how those problems were resolved through the use of existing data sources and the collection of new types of data. It closes with a discussion of several conceptual, methodological and procedural issues that will have to be faced in virtually any attempt to estimate the demographic consequences of natural disasters.

Key words: Applied demography, Natural disasters, State and local demography

Introduction

In the early morning hours of 24 August 1992, hurricane Andrew, a category 4 storm with winds gusting up to 175 miles per hour, slammed into the east coast of Florida about 20 miles south of Miami. Before crossing the state and exiting into the Gulf of Mexico, the storm exacted a terrible toll on the residents of South Florida. It killed at least 15 people, destroyed or damaged many thousands of homes and businesses and forced hundreds of thousands of people to find alternate living quarters. With total damages in excess of US$ 22 billion in Florida (mostly in Dade County), it was the most costly natural disaster ever to strike the USA. The hurricane had a tremendous and often tragic impact on many Floridians.

A far less serious but still significant consequence of hurricane Andrew was to greatly complicate the methodology used for producing state and local population estimates in Florida. The Bureau of Economic and Business Research (BEBR) at the University of Florida has a contract with the Florida Legislature to produce population estimates for each city and county in the state. The BEBR has received this contract each year since 1972, when the Florida Legislature established a revenue-sharing program in which popula-

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tion size plays the predominant role in the distribution of state dollars to local areas. Approximately US$ 1.4 billion was distributed to cities and counties during the 1994–1995 fiscal year, an average of more than US$ 100 per resident of Florida. Because of the size of this program and the impact of population estimates on the distribution of funds, the BEBR's estimates are closely scrutinized by local officials and their accuracy is frequently challenged.

Population estimates play a crucial role in other types of decision-making as well. They are used for developing city and county land use plans, estimating per capita incomes, regulating the pumping of water from underground reservoirs, calculating birth and death rates, defining market areas for automobile franchises, planning the location of retail outlets and countless other purposes. The accuracy and timeliness of these estimates is critical to the success or failure of many plans and projects in both the public and private sectors in Florida.

The BEBR uses the housing unit method of population estimation, in which estimates of permanent residents are based on estimates of the number of households. The hurricane literally blew away a substantial portion of the housing stock in southern Dade County (parts of mobile homes ended up in the middle of the Everglades). Data series were disrupted and statistical relationships were altered, reducing or completely destroying the validity of the assumptions and techniques ordinarily used in applying the housing unit method. How can population estimates be made in the aftermath of such a natural and statistical disaster?

There is a large, diverse literature on the social, political and economic impact of natural disasters, but it offers little guidance in answering this question. Many analysts have considered the effects of disasters on income, employment, capital stock, tax revenue and other economic variables (e.g., Chang 1983; Ellson, Milliman & Roberts 1984; Gillespie 1991; West & Lenze 1994). Others have studied institutional and organizational responses to disasters (e.g., Oliver-Smith 1993; Stallings 1987); recovery and restoration following disasters (e.g., Bates & Peacock 1987; Haas, Kates & Bowden 1977); the effects of disasters on divorce rates, crime rates and other social variables (e.g., Friesema et al. 1979; Geipel 1989); and the psychological, behavioral and mental health consequences of disasters (e.g., Church 1974; Perry & Lindell 1978). Very few studies, however, have considered the demographic consequences of natural disasters.

The few studies explicitly considering demographic factors either have used decennial census data to estimate long-range population and housing effects (e.g., Wright et al. 1979) or have relied on ad hoc estimates made by third parties (e.g., Geipel 1989; Haas et al. 1977; Kimball & Bolton 1994). These ad hoc estimates tend to be informal, incomplete, undocumented and unreliable (Clark 1989; Friesema et al. 1979; Wright & Rossi 1981). I am not aware of any studies describing how to produce reliable population estimates following a highly disruptive natural disaster.

That is the objective of the present study. I begin by describing the estimation methodology normally used in Florida and the problems created by hurricane Andrew. Then I discuss how those problems were resolved and provide a summary of the estimation results. I close with a discussion of the several conceptual and methodological issues involved in estimating the demographic impact of a natural disaster and draw some final conclusions. The frequency and magnitude of recent earthquakes, floods and hurricanes in the United States illustrate the importance of finding ways to make accurate and timely population estimates following large-scale natural disasters.

Impact of hurricane on estimation methodology

The BEBR uses the housing unit method to estimate the populations of all cities and counties in Florida, USA. Under this method, population is calculated as the number of occupied housing units (households) times the average number of persons per household (PPH), plus the non-household population living in group quarters (e.g., college dormitories, military barracks) or without traditional housing (e.g., the homeless). Each of these three components can be estimated using a variety of data sources and techniques. This section briefly describes the data and techniques used to estimate households, PPH and the non-household population in Florida and discusses the methodological problems created by the hurricane. More detailed descriptions of the housing unit method and its application in Florida can be found in Smith (1986) and Smith & Cody (1994).

Households. Two different approaches are used for estimating the number of households. The first starts with the number of housing units counted in the most recent census and adds the number of building permits issued since that census, net of demolitions and adjusted to account for the average time lag between the issuance of permits and the completion of units. This provides an estimate of the current housing stock. Households are then estimated by applying occupancy rates to the stock of housing units, by type (single family, multifamily, mobile home). These rates are typically based on the occupancy rates reported in the most recent census.

The second approach relies on electric utility customers. For each city and county, a ratio is formed between the number of households counted in the most recent census and the number of active residential electric customers for the same date. This ratio is then applied to the current number of active residential electric customers (occasionally adjusting for shifts in seasonal populations and other factors), providing an estimate of the current number of households.

The hurricane created problems for both of these approaches. The validity of using the sum of building permits and census counts as a measure of the current housing stock was wiped out by the destruction of a large but un-

known number of housing units. Many other units were so heavily damaged that their occupants were forced to leave, making 1990 occupancy rates unreliable as indicators of current rates. For both of these reasons, the building permit approach to estimating households was rendered ineffective for a number of places.

The destruction of housing units and electric power lines also called into question the usefulness of historical household/electric customer ratios. It was not known how many people were living in places with no electric power, whether the power was still turned on in places that were no longer occupied, how frequently several households 'doubled up' and were served by a single electric meter, or whether the electric company's accounting system was able to keep pace with the rapid changes caused by the hurricane and the ensuing reconstruction. All these possibilities cast doubt on the reliability of household estimates based on electric customer data for places with heavy hurricane damage.

Persons per household. The average number of persons per household (PPH) is ordinarily estimated using a formula combining the local PPH calculated in the most recent census, the national change in PPH since that census (as measured by the Current Population Survey) and the local change in the mix of housing units since that census (single family, multifamily, mobile home). Local trends in PPH are based on national trends, but are adjusted up or down according to initial PPH values: when the national PPH is declining, local declines are generally greater when local PPH values are higher than national values and are smaller when local values are lower than national values. PPH estimates are also adjusted to account for changes in the local mix of housing units; multifamily units typically have lower PPH values than single family units.

PPH generally changes fairly slowly over time. With the hurricane, however, there was the possibility that large, abrupt changes had occurred. Was PPH the same for households forced to move by the hurricane as for households that did not move? Did dislocated people establish new households or move in with family or friends, thereby raising the PPH of households not directly affected by the hurricane? The latter possibility meant that the hurricane might have affected PPH values not only in the areas suffering the most severe housing damage, but in surrounding areas as well.

Non-household population. Population living in households accounts for almost 98% of the total population in Florida. The other 2% is composed of persons living in group quarters or other non-household arrangements. This population is normally estimated by collecting data directly from major group quarters institutions (e.g., colleges, prisons, military bases) and by assuming that the remainder of the non-household population stays the same proportion of total population as it was in the most recent census. The hurricane

made this assumption questionable. Many persons dislocated by the hurricane took up residence in tent cities, hotels, motels, short-term rental apartments and other types of shelter not typically used for housing permanent residents. The normal approach to estimating non-household populations could not determine how many people had moved into these types of shelter, where they were located or how long they stayed.

Dealing with the problems

The impact of the hurricane on the housing stock, occupancy rates, active residential electric customers, PPH and non-household populations meant that traditional data sources and estimation techniques were of doubtful usefulness for producing post-hurricane population estimates, at least for some places. What other data sources and techniques might be used, not only for the present study but for estimates following other disasters as well?

Potential data sources. One possibility is a survey conducted by the American Red Cross in the weeks immediately following large disasters in the USA. Field workers canvass the area, classifying housing units as destroyed (unrepairable), sustaining major damage (repairable, but uninhabitable until repairs are completed) or sustaining minor damage (inhabitable during repairs). For hurricane Andrew, the survey of Dade County counted 27,813 destroyed units, 51,850 suffering major damage and 54,189 suffering minor damage (American Red Cross 1992).

Data from Red Cross surveys typically become available soon after a disaster occurs, but provide no information on occupancy rates or PPH. Consequently, they do not provide enough information to produce reliable estimates of population change. Furthermore, several analysts have concluded that Red Cross surveys often underestimate the total number of damaged or destroyed units, sometimes by a substantial amount (e.g., Gillespie 1991; West & Lenze 1994).

A second potential source of data is insurance claims paid under homeowner and renter policies. These records often cover many more damaged units than Red Cross surveys and report the dollar value of losses, as well as the number of claims filed. They showed more than 500,000 homeowner and renter claims filed in Florida in the 20 months following Hurricane Andrew (Florida Department of Insurance 1994). However, insurance records do not cover uninsured losses and often provide no information on the geographic location of damaged units. As is true for Red Cross surveys, insurance records provide no information on occupancy rates or PPH.

A third potential data source is local administrative records. In Dade County, for example, the planning department developed estimates of destroyed housing units using data from property appraisal files (Metropolitan Dade County Planning Department 1993). These files covered the entire

county and were updated after the hurricane through field visits and the examination of aerial photographs. Housing units were classified as destroyed if their post-hurricane values were less than a specified proportion of pre-hurricane values (30% for single family and duplex units; 40% for multifamily units). This analysis showed a loss of 47,100 housing units in Dade County. Property appraisal data are useful because records refer to individual parcels and are updated over time, providing a basis for analyzing the geographic distribution of damages and monitoring the rate of reconstruction. However, they provide no information on changes in occupancy rates or PPH.

Other types of administrative records could also be explored. Examples include change-of-address records from the US Postal Service, annual migration estimates based on Internal Revenue Service tax return data and lists of addresses for telephone, electric, gas or water utility customers. The usefulness of these records depends on how quickly they become available after a disaster, the time periods and geographic regions they cover and how closely they track population movements. These characteristics will vary on a case-by-case basis; in the present case, these records were judged not to be useful.

A final potential source of data is the decennial census, which provides comprehensive housing and population data for all areas of the USA. Although the decennial census can be used to analyze the long-term demographic effects of natural disasters, it is of limited use for many purposes because it is available only once every ten years and does not monitor the frequency and timing of moves over the course of a decade.

To be most useful for our purposes, data sources must cover areas affected both directly and indirectly by the disaster, must reflect both housing damages and population movements, and must provide information for small geographic areas. None of the data sources discussed above – either individually or in combination with other sources – was found to be adequate for producing population estimates after hurricane Andrew.

We concluded that the only feasible way to collect the necessary data was through a series of sample surveys: one covering households in the area most directly affected by the hurricane, one covering households in surrounding areas and one covering hotels, motels and other types of shelter for the non-household population. These surveys were conducted in the summer of 1993, approximately one year after the hurricane. Each provided information on a different component of the housing unit method. The remainder of this section briefly describes the survey methodology; a more complete description can be found in Bureau of Economic and Business Research (1994).[1]

Field survey of hurricane area. The eye of the hurricane crossed Dade County about 20 miles south of Miami (Figure 1). Red Cross reports, aerial photographs and an examination of property appraisal data showed that damages were proportionally heaviest in the Florida City-Homestead area and became less severe as the distance to the north increased (areas of Dade County

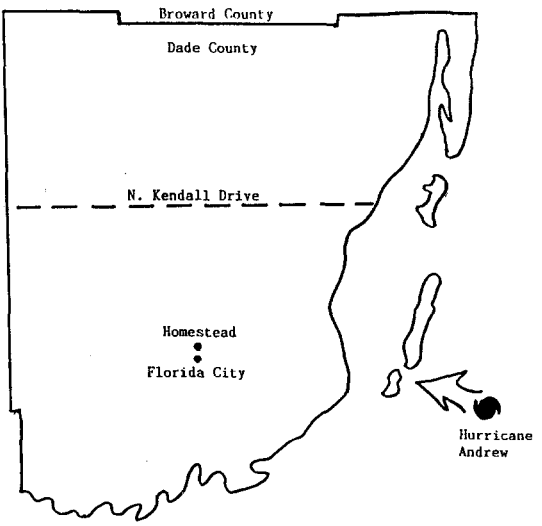

Figure 1. Map of Dade County and the hurricane area.

south of Florida City were largely unpopulated). North Kendall Drive was defined as the northern boundary of the 'hurricane area' because damages further north were relatively light (Metropolitan Dade County Planning Department 1993). The hurricane area included two small cities (Florida City and Homestead) and a large unincorporated area, with 1990 populations of 5,978, 26,694 and 316,380, respectively. Altogether, approximately 18% of Dade County's population lived in this area immediately prior to the hurricane.

To make population estimates for the hurricane area, we needed information on households, PPH and the non-household population. Information on PPH and the non-household population could be collected through telephone surveys, but data on households (or more precisely, occupancy rates) could be obtained only through a field survey of housing units. We contracted with the Institute of Public Opinion Research (IPOR) at Florida International University to conduct the field survey.

The central issues in the field survey were how to obtain a sampling frame, draw a sample and define a housing unit. Given our financial constraints and the high cost of field surveys, we decided to use some form of cluster sampling. We considered several possibilities for data sources that might be used as a sampling frame. Electric customer address lists could not be used because the hurricane had destroyed the statistical relationship between households and customers; furthermore, the electric company was reluctant to provide any data that might compromise customer confidentiality. Property appraisal records could not be used because they excluded mobile homes and did not provide information on the number of units in multi-unit

structures. In addition, property appraisal records did not include block codes, meaning that individual addresses would have to be sampled, making data collection very expensive.

We decided that the best approach was to draw a sample of blocks in Florida City, Homestead and the South Unincorporated Area and to interview a sample of units within each block. There were 4,763 census blocks in the hurricane area. IPOR divided them into three categories according to the number of housing units and the percent of rented units counted in the 1990 census. The first category consisted of 812 'marginal' blocks with fewer than 5 housing units each. These blocks had less than 2% of the area's 127,635 housing units in 1990. They were removed from the sampling frame to increase the efficiency of the estimates with little effect on bias. The second category consisted of 69 'special' blocks, each containing either more than 300 units or more than 50 units with at least 95% rentals. These blocks had 26% of the area's housing units in 1990. The third category consisted of 3,882 'regular' blocks with an average of 24 housing units apiece; these blocks contained approximately 72% of the area's housing units in 1990.

The unincorporated area was subdivided into four geographic zones, with the boundaries of the zones reflecting increasing distances from the path followed by the eye of the storm. Within the two cities and four zones, regular blocks were sampled using probability-proportional-to-size and randomly generated numbers were used to select a sample of housing units within each block. Special blocks were selected using simple random sampling and housing units within special blocks were selected using systematic sampling. Interviewers went to each housing unit, recording occupancy status, number of current residents and unit type (single family, multifamily, mobile home).

The primary objective of the field survey was to provide data that could be used to develop occupancy rates. To meet this objective, it was essential that housing units in the survey be defined in a manner consistent with the housing data that would form the basis for the household estimates. The basis for the household estimates was the housing unit counts from the 1990 census, augmented by the number of building permits issued since that time (net of demolitions). Interviewers were thus instructed to count all potential housing units, including those that were heavily damaged or even destroyed completely by the hurricane. Aerial photographs and property appraisal records were consulted to determine whether vacant lots contained any housing units prior to the hurricane. Heavily damaged or completely destroyed units were simply classified as unoccupied units.

Telephone surveys of households. According to preliminary evidence, the hurricane damaged or destroyed many thousands of housing units and forced hundreds of thousands of residents to make alternate living arrangements. Many residents undoubtedly left the area or even the state, but many more moved in with friends or relatives or into hotels, motels, community shelters or unoccupied houses and apartments in the area. The hurricane thus affected

the populations of nearby areas that suffered little or no direct hurricane damage.

All the cities in Dade County were potentially affected by population outflows from the hurricane area, and perhaps cities in Broward County as well (just north of Dade County). Since the hurricane did relatively little major structural damage in these neighboring places, it was not necessary to conduct a field survey of housing units. Rather, we could follow our normal approach of estimating households from electric customer and/or building permit data. However, it was necessary to conduct a survey of households to determine whether hurricane-related migration had caused any significant changes in PPH values.

Since our contract with the Florida Legislature requires population estimates for all counties and incorporated places, it was necessary to conduct surveys in all cities and the unincorporated area of Dade County. We also conducted surveys in six cities in Broward County: two each in the southern, central and northern parts of the county. If the variation in results had been found to be high in Broward County, we were prepared to conduct surveys in additional cities as well (this turned out not to be necessary).

The BEBR has a well-established survey program with the equipment and expertise needed to conduct telephone surveys. The major issue was whether to contact households through Random Digit Dialing (RDD) or to obtain a list of residential telephone numbers from the telephone company. The advantage of RDD is that all residences with a telephone can potentially be reached, including those with unlisted numbers. The disadvantage is that a large proportion of calls reach businesses or non-working numbers, making it expensive and time-consuming. More important for our purposes, with RDD city codes could not be attached to specific telephone numbers, making it impossible to draw a random sample of households for each city.

We therefore decided to use a list of residential telephone numbers by city as a sampling frame. This list was provided by the telephone company and contained 457,521 numbers for Dade County and 446,906 for Broward County (unlisted numbers account for 30–40% of total residential customers in Dade County and 20–30% in Broward County). Random samples were drawn for each city and unincorporated area, with target sample sizes set at 400 each (except for cities with fewer than 400 listed customers, where all available numbers were called). Telephone numbers at which there was an answering machine or no answer were called up to nine times before they were dropped from the sample. Overall, about 52% of calls resulted in completed interviews.

The primary objective of this survey was to determine whether PPH had changed during the year following the hurricane. We asked questions regarding the number of permanent residents currently living in the household and the number living there immediately prior to the hurricane. We also asked whether any (or all) residents of the household had moved there because the hurricane damaged or destroyed their previous residence or had moved

there from other parts of the state or nation to work in jobs created by the hurricane (e.g., construction, clean-up). In both cases we asked questions regarding how long these movers had lived there, how much longer than intended to stay and where they planned to go when they left.[2]

Non-household surveys. Some of the people displaced by the hurricane moved into hotels, motels, trailer parks, short-term rental apartments and other types of shelter not picked up in our usual measures of households. People with these living arrangements would most likely not be covered by the list of residential numbers provided by the telephone company. The third set of surveys was designed to estimate this group.

We obtained a list of telephone numbers for hotels, motels, transient apartments and rental condominiums from the Florida Department of Business Regulation; numbers for RV and mobile home parks were obtained from the Florida Department of Health and Rehabilitative Services. We contacted all the establishments in Dade and Broward Counties for which telephone numbers were available. Interviews were conducted with the manager of each establishment, asking questions about the number of rooms (units) occupied by permanent residents at the current time (summer of 1993) and the number occupied by permanent residents immediately prior to the hurricane. We also asked about the number of persons occupying those rooms (units). Just over half the calls led to completed interviews: some of the telephone numbers were invalid, some establishments had gone out of business, some managers refused to cooperate and some were unable to provide the requested information.

A summary of results

As expected, the field survey of the hurricane area showed that occupancy rates were dramatically lower in 1993 than in 1990 (Table 1). For Florida City, occupancy rates declined from 0.871 to 0.539; for Homestead, from 0.865 to 0.620; and for the South Unincorporated Area, from 0.927 to 0.753. The hurricane clearly forced many people to leave their homes.

Household estimates were made by applying survey occupancy rates to the estimated number of housing units for each place (Table 2). Housing unit estimates were based on the number of units counted in the 1990 census, plus the number of building permits issued since that time (adjusted for estimated construction time) and the number of Federal Emergency Management Agency (FEMA) mobile homes placed in the area (we assumed that 98% of the FEMA units were occupied). Multiplying the number of units by the occupancy rates provided estimates of the number of households on 1 August 1993 (the approximate date of the survey). These were transformed into estimates for 1 April 1993 (the date required for population estimates in Florida) using electric customer data: the ratio of households/customers

Table 1. Field survey occupancy rates, by place and type of block

Place/type	Total units	Occupied units	Occupancy rate	1990 Rate
Florida City				
Regular	154	83	0.539	0.871
Homestead				
Regular	258	180	0.698	
Special	112	35	0.313	
Total*	–	–	0.620	0.865
South Unincorp.				
Regular	1,334	1,057	0.792	
Special	715	425	0.594	
Total*	–	–	0.753	0.927

* The total occupancy rate was calculated as the weighted average of the rates for regular and special blocks, with the weights determined by the proportion of housing units in regular and special blocks in 1993.
Source: Bureau of Economic and Business Research, University of Florida.

Table 2. Household estimates for Florida City, Homestead and South Unincorporated Dade County: 1 April 1993

Place/type	1.08.93 Units	Occupancy rate	1.08.93 Households	1.04.93 Households*
Florida City				
Regular	2,083	0.539	1,123	
FEMA	97	0.980	95	
Total	2,180		1,218	1,255
Homestead				
Regular	8,856	0.698	6,181	
Special	2,259	0.313	707	
FEMA	599	0.980	587	
Total	11,714		7,475	6,497
South Unincorp.				
Regular	91,291	0.792	72,302	
Special	33,362	0.646	21,552	
FEMA	2,272	0.980	2,227	
Total	126,925		96,081	93,535

* Households for 1 April were estimated by applying the ratio of August households/August electric customers to the number of electric customers on 1 April.
Source: Bureau of Economic and Business Research, University of Florida.

in August was applied to the number of customers in April. This procedure led to estimates of 1,255 households in Florida City, 6,497 in Homestead and 93,535 in the South Unincorporated Area.

Telephone surveys often overstate PPH because large households are more likely than small households to have a household member at home when the interviewer calls. In addition, there is often a substantial amount of variation in the number of residents per household, leading to wide confidence

intervals around the sample estimate of PPH.[3] For these reasons, we did not use survey data to estimate PPH directly. Rather, we focused on whether PPH had changed significantly between 1992 and 1993. To accomplish this, we collected data on the number of persons living in the household in the summer of 1993 and the number living there immediately prior to the hurricane (summer of 1992). Comparing these two numbers provides an indication of whether PPH had increased due to the 'doubling up' of households caused by the hurricane. We also collected data on PPH for households in which no member was living at the current address at the time of the hurricane (i.e., new households).

The results are shown in Table 3. For most places, PPH in 1993 was similar to what it had been in 1992. There was no indication of a widespread doubling up of households. In fact, PPH was higher in 1993 than 1992 in only nine out of 35 places; these differences were never very large. In addition, PPH for households established after the hurricane was generally smaller than PPH for pre-hurricane households. Few of these differences were found to be statistically significant.[4] We concluded that there was no evidence that PPH had changed significantly as a result of hurricane-induced population movements and that normal estimation procedures could be used without further adjustment.[5]

PPH undoubtedly rose in many places during the weeks immediately following Hurricane Andrew, as people whose homes were damaged or destroyed moved in with friends or relatives. However, it appears that those moves were relatively short-lived and had no impact on PPH a year later. This finding was corroborated in a later study focusing explicitly on population shifts caused by the hurricane (Smith & McCarty 1996).

We surveyed 1,918 hotels, motels, transient apartments, condominiums and mobile home/RV parks in Dade and Broward Counties. The data indicated little change in the number of permanent residents living in these types of housing. Only three cities showed changes large enough to merit population adjustments: Miami Beach, Fort Lauderdale and Hollywood. We estimated that non-household populations had increased by 250, 200 and 200 in these three cities, respectively. Again, it is likely that the number of displaced residents living in these types of shelter was much larger in the weeks immediately following the hurricane than it was a year later.

We made population estimates for Florida City, Homestead and the South Unincorporated Area using the household estimates shown in Table 2, the PPH reported in the 1990 census and the non-household population multiplier derived from 1990 census data (adjusted for the group quarters loss reported for Homestead Air Force Base). For the remainder of Dade County and for Broward County, we used our normal estimation procedures. Estimates for 1 April 1993 are shown in Table 4.

Compared to 1 April 1992, the 1993 estimates showed population declines of 1,978 in Florida City, 8,355 in Homestead and 56,626 in the South Unincorporated Area. All three of these areas had grown between 1990 and 1992.

Table 3. Mean number of persons per household (PPH) by City, 1992 and 1993

Place	N	PPH-1992	PPH-1993	Difference
Dade County				
South Unincorp.	461	3.17	3.15	–0.02
Kendall Unincorp.*	358	2.99	2.88	–0.11
North Unincorp.	322	2.89	2.87	–0.02
Bal Harbour	282	1.86	1.85	–0.01
Bay Harbour Island	313	1.93	1.93	–
Biscayne Park	336	2.70	2 64	–0.06
Coral Gables*	350	2.67	2.73	0.06
El Portal	273	2.73	2.72	–0.01
Florida City	372	3.46	3.38	–0.08
Golden Beach	84	3.33	3.37	0 04
Hialeah	368	3.10	3.06	–0.04
Hialeah Gardens*	350	3.25	3.14	–0.11
Homestead	336	3.05	2 99	–0.06
Indian Creek Village	6	3.33	3.33	–
Key Biscayne	309	2.57	2.61	0.04
Medley*	116	2.35	2.17	–0.18
Miami	400	2.82	2.81	–0.01
Miami Beach	344	2.09	2.10	0.01
Miami Shores	372	2.73	2.75	0.02
Miami Springs	370	2.74	2.67	–0.07
North Bay	305	2.20	2.20	–
North Miami	348	2.82	2.79	–0.03
North Miami Beach	325	2.77	2.74	–0.03
Opa-Locka	370	3.17	3.17	–
South Miami	369	2.69	2.66	–0.03
Surfside	301	2.45	2.46	0.01
Sweetwater	387	3.41	3.41	–
Virginia Gardens	314	2.69	2.75	0.06
West Miami	365	3.01	2.97	–0.04
Broward County				
Coral Springs	387	3.19	3.21	0.02
Ft. Lauderdale*	366	2.24	2.17	–0.07
Hollywood	358	2.49	2.50	0.01
Pembroke Pines	361	2.51	2.48	–0.03
Pompano Beach	369	2.21	2.21	–
Tamarac*	359	2.08	2.03	–0.05

* 1993 PPH is significantly different than 1992 PPH at 0.05.

N = sample size.

Note: PPH values refer to households in which at least one resident was present in both 1992 and 1993.

Source: Bureau of Economic and Business Research, University of Florida.

Table 4. Population estimates, 1992 and 1993

Place	1992	1993	Change	% Change
Florida City	6,067	4,089	–1,978	–32.6
Homestead	27,087	18,732	–8,355	–30.8
South Unincorp.	334,201	277,575	–56,626	–16.9
Total (South Dade)	367,355	300,396	–66,959	–18.2
Remainder (North Dade)	1,615,253	1,650,427	35,174	2.2
Dade County	1,982,608	1,950,823	–31,785	–1.6
Broward County	1,294,090	1,317,512	23,422	1.8

Source: Bureau of Economic and Business Research, University of Florida.

North Dade and Broward County picked up some of the outflow from South Dade, growing by 35,174 and 23,422, respectively; these gains were considerably larger than the average annual increases from 1990 to 1992. Hurricane Andrew clearly had a significant impact on the short-run population distribution in South Florida.

What about the long-term population distribution? Several studies have concluded that natural disasters have no significant long-term effects on local population growth in the USA (e.g., Wright et al. 1979; Friesema et al. 1979). However, few disasters have had the impact of Hurricane Andrew. Did local movers return to their pre-hurricane residences? Did those who left the county or the state return to Dade County? Will future moves be affected? The present study cannot answer these questions, but they are addressed in a follow-up study drawing on a survey which collected additional information and covered a longer period of time (Smith & McCarty 1996).

In the absence of the surveys described above, the 1993 population estimates for Florida City, Homestead and the South Unincorporated Area most likely would have been based on the standard methodology using electric customer data. This standard approach would have produced estimates of 4,565 for Florida City, 15,191 for Homestead and 285,035 for the South Unincorporated Area, which differ from the estimates shown in Table 4 by 476 (11.6%), 3,541 (18.9%) and 7,460 (2.7%), respectively. Since the revenue-sharing value for these places was approximately US$ 75 per person for fiscal year 1994–1995, the standard estimates would have meant funding differences of US$ 35,700 for Florida City, US$ 265,575 for Homestead and US$ 559,500 for the South Unincorporated Area, compared to the estimates actually used.

The data collection efforts and demographic analyses described in this article thus had a substantial impact on the distribution of revenue-sharing funds in Florida. They also helped raise public confidence and the level of political acceptability of post-hurricane population estimates. Both of these effects improved the quality of decision-making in Florida.

Discussion

A number of the lessons learned in making post-Hurricane Andrew population estimates can be generalized. Perhaps most important, the major problem in analyzing the demographic impact of almost any large-scale natural disaster will be the paucity of relevant data. Traditional indicators of population change either lose their validity (e.g., building permits, electric customers) or become available too late to be useful for most purposes (e.g., decennial census data). Red Cross data typically become available within a few weeks after a disaster, but contain no information on population movements per se and appear to understate the magnitude of housing damage and destruction. Insurance and property appraisal records contain useful information on damages, but generally do not provide sufficient geographic and demographic detail to develop estimates of population shifts. Postal delivery records are potentially useful sources of information, but are not always available and may be difficult to interpret as indicators of population change. Developing reliable data sources is the critical challenge for research on the demographic impact of natural disasters.

Sample survey data will generally be needed before any detailed demographic analyses can be performed. Collecting those data can be expensive and perhaps controversial. We contacted the economic and demographic research staff of the Florida Legislature soon after the hurricane, requesting survey research funds. They were receptive to our proposals, but were initially opposed by several political interest groups in Dade County who believed it was better to have imprecise and unsubstantiated estimates than to develop more precise estimates that would most likely document a substantial population decline! Such opposition is perhaps not surprising, given the potentially adverse impact post-hurricane population estimates might have on the distribution of state revenue-sharing dollars to some local governments. This controversy was eventually resolved, but data collection efforts were delayed by several months.

Political controversies are certainly not unique to Florida or Dade County. Conflicts may also arise regarding the types of data to be collected, the methods used, the areas covered, the costs involved and the purposes for which the data will be used. Large-scale disasters can upset the control of resources and the balance of political and economic power in the affected areas (Oliver-Smith 1993). Conflicts of interest and funding problems may therefore have to be resolved before primary data collection efforts can be launched following a natural disaster.

A difficult issue for post-disaster survey research is choosing the appropriate survey population. Some residents remain in the same location as before the disaster, some have moved to a different location in the same general area and others have left the area completely. What is the relevant survey population under these circumstances? The answer to this question will depend on the purposes for which the survey data will be used. The task

described in the present study was to develop population estimates for 1 April 1993; it was therefore appropriate to draw samples based on the housing stock and resident population as of that date (or as close to that date as possible). If the objective were to estimate the proportion of the pre-disaster population that changed residence, however, a different survey population would have to be chosen. Whatever the objective, it is essential that the choice of the survey population be consistent with the types of estimates that will be made. This will often be a complex and challenging issue.

A related problem is choosing a sampling frame which adequately reflects the survey population. Various types of administrative records are potentially useful, although care must be taken to ensure that the disaster did not alter the procedures used in compiling and tabulating the records. GIS systems containing property appraisal records, building permits, electric customer records and similar types of data are potentially useful because they provide information on the geographic location of households or housing units. Comprehensive GIS systems containing these types of data are relatively rare today but promise to become more prevalent in the future.

Whatever survey population and sampling frame is chosen, the concepts and definitions used in the survey must correspond exactly to those occurring in the base data to which the survey characteristics will be applied. In the present study, for example, it was essential that the occupancy rates derived from the survey be based on the same definition of a housing unit as was used in constructing the estimate of the total housing stock. But what constitutes a housing unit when many units have been partially or fully destroyed and residents are living in tents, RVs and even demolished units? Census Bureau guidelines for defining housing units no longer apply. Researchers must be prepared to change their normal definitions, assumptions and techniques in the aftermath of a large natural disaster; this can be particularly problematic when the disaster itself may have changed some basic concepts.

Another issue in post-disaster demographic research is deciding what types of data to collect. This will be determined primarily by the purposes for which the survey data will be used; it may be a difficult task because some of the relevant issues may not become apparent until after the survey has been completed and data analysis has begun. In the present case, the primary objective was to collect data for making estimates of total population; namely, occupancy rates in the hurricane area and PPH and non-household populations in both the hurricane area and surrounding areas. We collected other types of data as well, but they were strictly of secondary importance. We have since collected additional data on the extent of hurricane damages, moves caused by the hurricane, post-hurricane living arrangements and plans for future moves. These data are useful for answering other questions regarding the demographic impact of the hurricane.

Finally, attempts to estimate the full demographic impact of a natural disaster must focus on several points in time, either by collecting data at

different times or by asking questions about circumstances at different times. The failure to do so will give an incomplete or even misleading view of population movements because large-scale disasters induce a series of short-term, temporary moves as well as long-term, permanent moves. For example, hurricane Andrew forced hundreds of thousands of people to leave their homes, but many returned after a week or two, some stayed away for several months and others will never return. Many people made several moves before establishing a new permanent residence. The present study provides a snapshot view of the post-hurricane population at one point in time; a follow-up study considers a broader range of hurricane-induced population movements over time (Smith & McCarty 1996).

Conclusion

Accurate and timely population estimates are crucial for many types of decision-making in both the public and private sectors. The occurrence of natural disasters can greatly complicate the production of such estimates. This article describes an approach to making population estimates following a large-scale natural disaster, an approach born of necessity and developed with little guidance from previous research. It describes a number of conceptual and methodological problems that will generally have to be faced after a disaster and discusses some approaches to dealing with those problems. Perhaps more important, it provides a point of departure for future research, which will surely produce refinements, extensions and entirely new approaches. The growing impact of natural disasters on human populations magnifies the importance of this line of research.

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Notes

1. This article describes only the surveys and data used for making estimates of total population

for 1 April 1993. Other types of survey data were also collected during 1993 and 1994 and have been used for additional analyses (e.g., Smith & McCarty 1996).

2. We conducted a follow-up survey using RDD to determine whether households with listed numbers differed from those with unlisted numbers with respect to hurricane-induced migration and changes in PPH. The results showed no significant differences. We concluded that using listed telephone numbers as a sampling frame did not lead to biased estimates.
3. For example, the sample PPH for Miami was 2.78, but a 95% confidence interval ranged from 2.62 to 2.94. For Fort Lauderdale, a 95% confidence interval ranged from 2.03 to 2.27 and for Hialeah it ranged from 2.91 to 3.17. Given the sample sizes, these ranges are not unusual for estimates of PPH.
4. The 1993 PPH was significantly different than the 1992 PPH in only 6 of 35 places, at a 95% level of confidence. In 5 of those 6 places, the 1993 PPH was lower than the 1992 PPH. In addition, the PPH for households established after the hurricane was significantly different from the PPH of pre-hurricane households in only 3 places; in all 3, the PPH for new households was lower than the PPH for pre-hurricane households.
5. Since it was suspected that PPH might have risen for some areas, the finding that no significant change had occurred was just as important for the accuracy and political acceptability of the population estimates as a finding that significant change had occurred would have been.

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